Essays in Economic Policy and Development

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The Faculty of Economics, Business Administration and Information Technology of the University of Zurich hereby authorizes the printing of this dissertation, without indicating an opinion of the views expressed in the work.

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Contents

Part I

Dissertation Overview

Dissertation Overview

My dissertation consists of three chapters on Economic Policy and Development. In the first chapter, I use a general equilibrium trade model as in Eaton and Kortum (2002) to estimate the effect of transport infrastructure on regional development. I apply the analysis to India, a country with a weak and congested transportation infrastructure. I first analyze the effect of a recent Indian highway project that improved connections between the four largest economic centers. I estimate the impact of this new transportation infrastructure on income across Indian districts using satellite data on light intensity at night. The results show aggregate net gains from this recent highway project, but very unequal effects across districts. China has followed a different strategy in designing its highway network and has experienced more convergence across regions than India. I therefore use the model to quantify the effects of a counterfactual transportation network for India that replicates the Chinese strategy of connecting intermediate-sized cities with modern highways. I find that such a counterfactual network would have significantly benefited the lagging regions of India, leading to a more equal regional development. However, the effects on average growth would have been modest. I also construct additional counterfactuals and discuss their effects on average and regional development.

The second chapter is joint work with Lin Shao and Fabrizio Zilibotti. We estimate the effect of the establishment of Special Economic Zones (SEZ) in China on its economic development. SEZ were geographically limited areas and usually located in cities. We use a panel of 276 Chinese cities and prefectures from 1988 to 2010. These zones were representative for the reform process in China since the late 1970s because they combined market mechanisms with a strong role of the state. Our baseline empirical specification is a difference-in-difference estimator that exploits the variation in the establishment of SEZ across cities and years. We find that the long run effect of the establishment of a state-level SEZ is about a 20% increase in the level of GDP, but there is no evidence of a permanently steeper growth path. This finding is confirmed in a sub-sample of provinces in inland China, where the selection of cities to host the zones was transparent and based on administrative criteria. We also use a number of alternative specifications and find similar results. A decomposition of the effect of SEZ on GDP into different channels suggests that the effect of the SEZ worked mainly through the accumulation of physical capital. There is some weaker evidence of increasing productivity and human capital investments. To mitigate concerns about the quality of the GDP data, we use light intensity as an alternative measure for economic activity and also find a positive effect of SEZ.

The third chapter is joint work with Yikai Wang. We propose a theory of ethnic conflict and endogenous polarisation between ethnic groups. A political elite strategically initiates conflicts between two ethnic groups in order to polarize them. It uses this divide-and-rule strategy to sustain its own power as an elite, which allows it to tax people and extract rents. We model polarization as a lack of trust in order to provide a micro-foundation for how the elite can induce the groups to polarise even though people are rational. Trust is shaped by trade interactions between different groups as in Rohner, Thoenig, and Zilibotti (2013). Low trust implies low expected gains from trade. By starting a conflict and thereby interrupting trade, the elite can stop trust between the two groups from emerging. The elite follows this strategy in situations where it faces a large threat of revolution. This threat can originate in the common interest of people of both ethnic groups to reap gains from peaceful trade without being taxed by the elite. This is more likely to be the case if current trust levels are high or if the cost of revolution is low.

Policy plays a crucial role in all three chapters and the insights we gain point towards an important role of the state. Transport infrastructure connects markets and thereby allows agents to reap gains from trade. These interactions between market participants are complex and generate externalities that call for coordination. The combination of general equilibrium trade theory with disaggregated data on economic activity employed in the first chapter allows comparing the effects of different ways in which a government may design infrastructure networks to connect markets. The second chapter shows how economic reforms and industrial policy have supported the development process during China's transformation. The interaction between regions with different economic policies clearly depends on the infrastructure connecting them – as is suggested by the first chapter. The benefits from integrating regions also depend on how beneficial trade is and trust between trade partners can be a crucial prerequisite to reap these gains from trade. The third chapter shows that trust can be strategically destroyed by political elites who provoke conflicts in order to sustain their own power. Policies to prevent such actions and to increase the gains from trade are therefore crucial.

Part II

Research Papers

1 Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development

1.1 Introduction

China and India, the two most populous countries in the world, are developing at unprecedented rates. Yet, their spatial, or regional, development patterns are surprisingly different. Throughout China, new clusters of economic activity emerge and there is a strong pattern of convergence across Chinese counties. In contrast, a substantial number of Indian districts of intermediate density experience low growth and there is generally less convergence. While such differences in the spatial development of China and India have been documented in the literature (Desmet et al., forthcoming; Chaudhuri and Ravallion, 2006), we still lack precise explanations and possible policy measures.

This paper links the differences in the spatial development of the two countries to their transport networks. The Indian government launched a national highway project in 2001 that improved connections between the four largest economic centers Delhi, Mumbai, Chennai, and Calcutta with the "Golden Quadrilateral" (GQ). In contrast, China built a National Expressway Network (NEN) that had the explicit goal of connecting all intermediate-sized cities with a population above 500,000 and all provincial capitals with modern highways. Overall, China invested about ten times more in its highway network than India, which is seen as being severely constrained by its insufficient infrastructure (Harral et al., 2006).

If transport infrastructure is a determinant of development, then one may ask how a network should be designed in order to foster growth and regional development. In this paper, I first identify the effect of a major highway project in India, the construction of the GQ. Then, in light of the stark difference in the transport infrastructure strategies of India and China, I ask how India would have developed if it had built a network like the Chinese NEN. To this aim, I construct a counterfactual Indian highway network that mimics the Chinese approach of connecting intermediate-sized cities. The counterfactual is built based on the precise location of cities and on the topographic features of India, which are modeled using a geographic information system (GIS). The paths of the counterfactual highway connections are chosen to minimize the construction costs based on slope and land cover. The resulting road network then allows me to compute bilateral transport costs between all 590 mainland districts in India using a shortest path algorithm. In the empirical analysis, the bilateral transport costs are related to income, which is measured using data on luminosity at night. This data is available from satellite images and captures human economic activity at a high spatial resolution and over time. Luminosity has been shown to be a good proxy for income growth (Henderson et al., 2012) and can be aggregated with digitized maps to the level of districts, for which official GDP data is not available.

The empirical analysis builds on general equilibrium trade theory. I follow Donaldson and Hornbeck (2013) who derive from a Ricardian trade model a reduced-form measure for the aggregate impact of transport infrastructure on income.[1] This reduced form captures the *market access* of a location by summing over the income of trading partners, discounted by the bilateral trade costs and by the destination's market access.[2] Transport infrastructure determines bilateral trade costs such that changes in the infrastructure over time generate variation in market access. More precisely, the bilateral transport costs can be computed for the transport network in 2000 (before the start of the recent Indian highway project), in 2009 (after completion of the first phases), and for the counterfactual (replicating the Chinese network). The resulting bilateral transport costs are then used to derive districts' market access for each version of the transport network.

The model predicts a log-linear relationship between income and market access. The time variation in market access between the actual networks in 2000 and 2009 allows me to estimate this relationship. Given the resulting estimate for the elasticity of income with respect to market access, I predict each district's income based on the market access implied by the counterfactual network. Importantly, market access captures the general equilibrium consequences of transport infrastructure and the resulting predictions therefore represent aggregate effects.[3]

The empirical analysis makes three contributions. First, I quantify the aggregate effect of the realized GQ, India's major highway investment project between 2001 and 2009. The results suggest that aggregate income was 2.4 - 3.5 percent higher in 2009 than it would have been if the GQ had not been built. This implies a gain after one decade that is more

[1] Donaldson and Hornbeck (2013) estimate the effect of American railways on land value, while I estimate the effect of Indian highways on real income. Sections 1.4 and 1.5 will discuss the differences in more detail.

[2] A related measure is *market potential*, which has been derived from models in the new economic geography literature. See for example Redding and Venables (2004) and Hanson (2005).

[3] An increase in market access of the trading partner (e.g. because it is better connected to a third district) can reduce the market access of an origin. Market access therefore captures general equilibrium consequences such as trade diversion (see Section 1.5).

than three times the construction costs. Second, I predict the aggregate effects of the counterfactual transport infrastructure, which replicates the salient aspects of the Chinese network in India in a way that minimizes road construction costs. Taking into account the construction costs of counterfactual roads, the results imply in the aggregate a modest difference relative to the existing infrastructure. The third contribution is to evaluate the distributional consequences of the actual and counterfactual networks. The results show that initially less developed regions would gain substantially from the counterfactual. The reason is that this network, by connecting all intermediate-sized cities, also reaches into regions that previously had low growth and were neglected by the GQ. Thus, a transport network that follows the Chinese strategy would increase growth particularly in India's lagging regions. This provides an explanation for the weaker convergence in India compared to China. Two alternative ways to replicate the Chinese network in India lead to qualitatively similar results.

The distributional consequences are particularly relevant in light of the unequal regional development of India. Policy makers are aware of this and the national highway development strategy did include plans for other highway connections besides the GQ. In particular, the government planned the North-South and East-West Corridors which cross through regions that were not reached by the GQ. However, these other projects were delayed and by 2009 only a small part has been finished. In an additional counterfactual exercise, I find that the completion of these corridors would indeed increase income in some of the lagging states. However, the explicit strategy of connecting all intermediate-sized cities would have larger aggregate effects and benefit more lagging districts.

The remainder of the paper is structured as follows. Section 1.2 reviews the related literature. Section 1.3 discusses the spatial development and transport infrastructure in India and China. Section 1.4 shows how the counterfactual network is constructed and what data is used. Section 1.5 presents the conceptual framework and Section 1.6 discusses the results. Section 1.7 shows alternative ways to replicate the Chinese network and discusses the robustness of the results. Section 2.6 concludes.

1.2 Related Literature

The role of transport infrastructure for development has been the subject of a large literature.[4] A recent increase in this literature was triggered by a combination of economic theory with geographic information such as the exact location of transport infrastructure. My methodology for evaluating the impact of infrastructure builds on Donaldson and Hornbeck (2013) who estimate the aggregate effect of the expansion of the American

[4]See for example Redding (2010) and a recent survey by Breinlich et al. (2013).

railway network in the 19th century. They derive market access as a reduced form measure for the impact of transport infrastructure in a general equilibrium trade model as in Eaton and Kortum (2002). Donaldson and Hornbeck (2013) also compare the effect of the actually built network to counterfactual scenarios in which railways are replaced by roads and canals.[5] I adapt their framework to the use of light data as a measure of real income in India. To determine the precise paths of the counterfactual roads, I use the least-cost network that connects a given set of cities. Such a network has previously been used by Faber (2013) within China in order to construct an instrument for the actually built highways. I follow the approach of connecting cities which fulfill the criteria of the NEN in a way that minimizes road construction costs, but I apply it to Indian cities and to the local terrain in order to construct a counterfactual network.

While the empirical analysis in this paper builds on general equilibrium trade theory, it is also related to several recent studies on the local effects of transport infrastructure. Datta (2012) and Ghani et al. (2012) study the effects of the GQ and find a positive impact on firms located in the proximity of the new highways.[6] An important aspect of these studies is the identification of exogenous sources of variation in transport infrastructure. They rely on an identification strategy similar to the one proposed by Chandra and Thompson (2000) and Michaels (2008) who estimate the effect of US highways on counties that lie between two important nodal cities. This is based on the observation that the highways were built to connect larger cities and thereby passed through other counties which consequently obtained access to the new transport infrastructure without being targeted. The results of Datta (2012) and Ghani et al. (2012) suggest positive effects on firms located close to the GQ. I use this strategy in order to estimate the effect of the GQ on non-nodal districts, excluding the four cities that were targeted by the GQ. Several related studies have analyzed the Chinese transport network (see Banerjee et al., 2012; Baum-Snow et al., 2013; and Faber, 2013).[7]

The above studies focus on identifying the local effects in the proximity of new roads. Two recent contributions that estimate the general equilibrium consequences of the national transport infrastructure in India and China are Donaldson (forthcoming) and Roberts et al. (2012). Donaldson (forthcoming) estimates the effect of railways in colonial India and finds that historical income levels of Indian districts had increased by 16 percent when they were connected to the railway network. He also shows that there is a sufficient statistic for the general equilibrium effect of transport infrastructure on in-

[5] Such a counterfactual exercise was also proposed in the seminal work by Fogel (1964).

[6] Both studies use firm surveys to evaluate the effect of the GQ. Ghani et al. (2012) point out that it would be valuable to estimate the effect with luminosity data.

[7] Transport infrastructure in other countries has recently been studied by Atack (2008), Baum-Snow (2007), Gollin and Rogerson (2010), Herrendorf et al. (2012), and Storeygard (2013).

come, which explains most of the variation due to transport infrastructure. Roberts et al. (2012) use a structural new economic geography model to measure the aggregate effect of the expansion of the NEN in China and find that aggregate income was 6 percent higher in 2007 due to the NEN. My analysis differs from the above studies by estimating the aggregate effect of transport infrastructure through market access, as was proposed by Donaldson and Hornbeck (2013), and using this estimate to predict income under various counterfactual infrastructures. To identify exogenous variation in market access, I apply the above-mentioned identification strategy by Chandra and Thompson (2000) and Michaels (2008).

The market access approach used in this paper is closely related to models in the new economic geography literature. Several authors analyze the role of market access (or market potential), which can be affected by transport costs (Puga, 2002; Redding and Venables, 2004; Hanson, 2005; Redding and Sturm, 2007; Head and Mayer, 2011, 2013). They find that market access is associated with trade, income, and population within and between countries. This paper also relates more broadly to a large literature on trade, in particular on the gravity structure (Anderson and van Wincoop, 2003; Allen and Arkolakis, 2013, Atkin and Donaldson, 2013; Coşar and Fajgelbaum, 2013; Redding, 2012). Head and Mayer (2011) point out that the gravity structure and market access can be derived from various trade models with different market structures and sources of gains from trade. A contribution of this paper is that the digital transport network can model explicitly how trade costs and thus proximity change due to transport infrastructure. Thus, changes in transport costs generate variation in market access which allows to study the relationship between income and market access over time. While these models are static, Desmet and Rossi-Hansberg (forthcoming) propose a model of spatial development based on technology spillovers where growth depends on the density of economic activity.

The assessment of the development effects of transport infrastructure also relates to cost-benefit analyses of individual infrastructure investments. For example, as a major investor in transport infrastructure in developing countries, the World Bank has developed procedures to evaluate the effectiveness of infrastructure projects (see World Bank, 2007a for an overview). While those concepts have advantages in capturing project-specific aspects such as safety and road deterioration, the methodology applied in this paper is able to capture the general equilibrium effects at a large scale, which allows evaluating and comparing national infrastructure strategies.

1.3 Spatial Development and Transport Infrastructure

This paper makes a link between regional growth and transport infrastructure. India and China provide an interesting context to study this relationship. While both countries are growing fast, they also show substantial differences in their regional development patterns and in their transport infrastructure. This section first reviews the evidence on the spatial distribution of income and growth in the two countries and then discusses their transport infrastructure.

1.3.1 The Spatial Development of India and China

During the past two decades, real GDP per capita in India has been growing at an average rate of 4.8 percent (World Bank, 2013). China's growth, averaging at 9.2 percent, has been even more spectacular and its income per capita overtook India's in the early 1990s. Although there is substantial variation in the regional growth rates within both countries, previous studies found that China has overall seen more convergence (Desmet et al., forthcoming; Chaudhuri and Ravallion, 2006). The same finding emerges when using light as a measure of income.[8]

Figure 1.1 shows the spatial distribution of light in the year 2000. Not surprisingly, there is a strong clustering of income in both countries. A similar picture arises when aggregating the light pixels to the sub-national units of Chinese prefectures and Indian districts. Interestingly, there are substantial differences in the spatial development over time. To illustrate this, Figures 1.2 and 1.3 show the spatial distribution of initial density and growth in the two countries. While China has seen the highest growth rates in prefectures with initially low density (measured as average light intensity per pixel in 2000), this has not been the case for Indian districts. In particular, the right panel of Figure 1.3 suggest that the districts with initially low or intermediate light density had experienced surprisingly low growth. This is consistent with the evidence presented in Desmet et al. (forthcoming) and Chaudhuri and Ravallion (2006) who found stronger convergence patterns in China than in India.[9]

While the finding that regional growth patterns differ between the two countries is well known, we still lack precise answers for what is driving these differences. Transport infrastructure is a potential candidate since it is an important determinant of the spatial

[8]Section 1.4 discusses the light data in more detail. Henderson et al. (2012) show that light correlates strongly with GDP in a panel of 188 countries.

[9]The observation is confirmed when regressing light growth of each prefecture or district on its initial density. The slope coefficient is significantly smaller in China than in India, suggesting stronger convergence.

distribution of economic activity. India and China indeed have followed different strategies for how to invest in their transport networks and these differences will be outlined next.

1.3.2 Transport Infrastructure in India and China

Infrastructure is a key determinant of transport costs and trade (Limao and Venables, 2001) and investments in transport infrastructure have been used extensively to promote development (World Bank, 2007a). India and China have both invested in their transport infrastructure during the past decades, but with different intensities and strategies (Harral et al., 2006). In this section, I first review the key elements of the infrastructure investments in the two countries and then discuss the construction of a counterfactual network for India which mimics the Chinese strategy.

In the early 1990s, the Indian road infrastructure was superior to the Chinese in terms of total km length and km per person, but both countries had about the same low quality of roads. Travel speeds on roads were further reduced by the simultaneous use by pedestrians and slow vehicles.[10] Over the 1990s, China's highway and railway network developed significantly faster than the Indian counterpart. In particular, it built the National Expressway Network (NEN) with the explicit objective of connecting all cities with more than 500,000 people and all provincial capitals in a modern highway system.[11] At that time, China's transport infrastructure was at risk of becoming a constraint for economic development which was gaining speed since the reforms started in the late 1970s (Asian Development Bank, 2007). The new network, shown in red in Figure 1.4, had reached a length of 40,000 km by 2007 and it continued to be expanded. It consists of four-lane limited access highways that allowed significantly higher driving speed than the existing roads.[12]

India also invested in its road infrastructure, but about ten times less than China and with a focus on the main economic centers. In particular, it launched a National Highways Development Project (NHDP) in 2001 and the first achievement of that project was the GQ, which connects the four major economic centers with four-lane highways (shown in green in Figure 1.4). Construction, mostly upgrades of existing highways to higher quality, began in 2001 and was completed by 2012 with a total network length of

[10]The railway infrastructure in the two countries was similar in terms of passengers but the Chinese railways transported four times more freight than the Indian railways. The numbers in this section are taken (if not otherwise stated) from Harral et al. (2006).

[11]This is also referred to as the National Trunk Highway System. The program was later expanded to include all cities with more than 200,000 people. See Chinese Ministry of Transportation (2004), World Bank (2007b), Roberts et al. (2012), and Faber (2013) for a discussion.

[12]A description of the history of the Chinese highway network and its different components is provided by ACASIAN. See `www.acasian.com` for further details.

5,846 km and at a cost of USD 6 billion (1999 prices).[13] The NHDP in India was not restricted to the GQ and also included the so-called North-South and East-West (NS-EW) Corridors. However, these projects were delayed and not fully completed by 2010. Figure 1.5 shows the parts which were completed by 2010.

The GQ in India, like the NEN in China, has significantly reduced the transport times between places with access to these new highways. The average driving speed on a conventional national highway (i.e. a highway which was not upgraded or built as part of the NHDP) was below 40 km/h (World Bank, 2002), while the driving speed on the GQ is around 75 km/h.[14] However, there is ample evidence that, even today, insufficient transport infrastructure is a severe constraint for the Indian economy. Raghuram Rajan, the current Governor of the Reserve Bank of India, recently stated that India needs to improve its infrastructure with the same discipline in order to catch up with China (FAZ, 2013). The same view is held by the World Bank and several consultancies and logistic firms, stating that a lack of adequate infrastructure hampers the regional development in India (World Bank, 2008; DHL, 2007; Ernst and Young, 2013; KPMG, 2013).

The road investment projects described above were among the largest inter-city transport infrastructure investments in the two countries and dominated investments in other means of transportation. The spending on the NEN in China was around USD 30 billion per year, roughly three times as much as its investments in the national railway system during the period 1992-2002. The importance of highways relative to railways also increased in India and the share of expenditures on railways in total transport infrastructure declined from 50% in the 1990s to 30% by the end of the 2000s (Ministry of Railways, 2012). Today, roads are by a large margin the most important transport mode in India, carrying 60% of the freight turnover compared to 31% for railways.[15] The highway projects undertaken in the two countries are therefore the crucial parts of their transport strategies and of high importance for the development of the two countries.

Although the analysis undertaken here captures a key aspect of the modern transport infrastructure in India and China, some caveats must be pointed out that concern possible changes in other types of infrastructure. But I will show that these concerns are mitigated by my empirical strategy which exploits exogenous variation in transport infrastructure and controls for location and time fixed effects. The first concern is the omission of other

[13]Most parts were already completed by 2007. See the webpage of the National Highway Authority of India (`http://www.nhai.org/index.asp`) for details. The cost estimates are based on Ghani et al. (2012).

[14]The official speed limit was increased to 100 km/h in 2007, but the actual driving speed is significantly lower. This was derived by selecting a random sample of locations and exporting bilateral transport times with a routine from google maps.

[15]The share of highways in the total freight turnover is even higher in India than in China (KPMG, 2013).

types of domestic transport infrastructure such as railways or urban transport systems such as subways. Second, access to international markets via sea ports or airports is not modeled as part of the transport network here. Third, villages' access to the transport infrastructure via rural roads is not considered due to a lack of precise data.[16] Finally, non-transport infrastructure such as electricity and water also affect economic development. However, these caveats would limit the validity of the exercise here only if the omitted factors were time-varying at the district level and correlated with the explanatory variable market access. Section 1.5 discusses in detail how I address this with a suitable empirical strategy.

The above discussion, and the illustration in Figure 1.4, makes clear that India and China have followed different strategies to improve their road infrastructure. While India's highway investments focused on connecting its largest economic centers with better highways, China has built a network that connects all cities that have a registered population of more than 500,000 and all provincial capitals. Furthermore, it is clear that highways play a key role in the overall transport infrastructure. India currently faces severe constraints due to insufficient transport infrastructure, which is less the case for China. A natural question therefore is how India would develop if it had a transport infrastructure like China. To answer this question, I propose a counterfactual road network for India by applying the policy objective of the Chinese government to identify the Indian cities which would be connected with the Chinese network. The exact routes are chosen such that the costs of building the roads, which depend on characteristics of the Indian terrain, are minimized. The next section will present the data that is required to build such a counterfactual network and to evaluate its effect on economic development.

1.4 Counterfactual Roads

In this section I build a counterfactual network of highways and compute bilateral transport costs. First, I use topographic features of India in order to determine the precise paths of the counterfactual roads such that road construction costs are minimized. Based on the geographically explicit road network, I then calculate the bilateral transport costs between all Indian districts using a shortest path algorithm. The data and methods required for this procedure are described next.

[16] According to Harral et al. (2006), India has prior to the start of the NHDP in 2001 focused its infrastructure investments on the improvement of roads which provide access to highways, while China has from the start of its program in 1992 put the emphasis on investments in arterial highways to connect cities. While I cannot observe the upgrades of local roads prior to my sample period, the NHDP was a large infrastructure program to which the Chinese NEN can be directly compared.

1.4.1 Data

In order to analyze the effect of transport infrastructure on economic development, I construct a dataset that incorporates the precise geographic location of different types of roads and of local income. I add to this data set the boundaries of Indian states and districts and multiple maps of the Indian terrain.

Transport Infrastructure and Terrain

I use geographic information system (GIS) methods to process the spatial data.[17] Digital maps with the location of the actual Indian transport infrastructure are taken from three sources: CIESIN (2013) provides a digitized road network that includes both highways and local roads. Esri (2013) also has digitized roads but is limited to the national highway networks. These first two sources allow to localize the current transport infrastructure in space, but they do not allow to accurately track changes over time and cannot distinguish the higher quality of today's GQ. Therefore, I use as a third source maps of the NHDP issued by the National Highway Authority of India (NHAI, 2010 and NHAI, 2013). These maps, which were digitized manually, show the location of several new highways, including the Golden Quadrilateral and the completed parts of the North-South and East-West Corridors. The average driving speed on existing roads are taken from several transport efficiency studies. World Bank (2005) reports that the typical driving speed on the existing Indian national and state highways is between 30 and 40 km/h and I therefore assume a speed of 35 km/h for all highways built before the start of the NHDP.[18] Roads of lower or unknown quality are also controlled for and the assumed travel speed is 25 km/h, which is suggested by surveys of rural Indian transport infrastructure (Liu, 2000). For areas where there are no roads reported in the digitized maps, I assume a travel speed of 10 km/h, which corresponds to the speed on unpaved roads (Roberts et al., 2012). The travel speed on the counterfactual network is taken to be the same as for the the Chinese expressways and the GQ, which according to google maps is 75 km/h. For a comparison of the highway networks, the digital maps of the Chinese expressway network were obtained from ACASIAN (2013).

In order to determine the construction costs for the counterfactual roads, I need digitized information on the terrain. I use digital elevation data produced by Jarvis et al. (2008) for a measure of slope. For land cover, I use the classification by the Global Land Cover Facility (2013) at the University of Maryland Department of Geography.

[17]The software used here are ArcGIS Desktop 10.1 and the spmat functions in Stata 13.

[18]These estimates are in line with more recent numbers by KPMG (2013).

Political Boundaries and Luminosity

The units of analysis in this paper are Indian districts. I focus on mainland districts, of which there are 590. Luminosity measured by weather satellites has been shown to be a good proxy for income (Henderson et al., 2012). Two important advantages of the light data are that is has a high spatial resolution and is independent of countries' statistical capacity. It is particularly useful when official GDP figures are not available, for example for subnational administrative units such as Indian districts.

The digitized district boundaries are provided by Global Administrative Areas (2012) and the light data is available from the Earth Observation Group (2013) of the National Geophysical Data Center of the United States. The satellite images originate from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) to detect cloud cover. The data is available from 1992 to 2012 as composites over cloud-free evenings.[19] The raster are 30 arc second grids, spanning -180 to 180 degrees longitude and -65 to 75 degrees latitude. To derive a measure of real incomeI for each district, I aggregate light within district boundaries using an equal area projection. The light summary statistics of the sample of mainland Indian districts are presented in Table 1.1.

In order to interpret the light data in terms of GDP, one first has to analyse the relationship between GDP and light. GDP data is not available for Indian districts such that the relationship has to be inferred from other samples. GDP at the level of sub-national units such as districts is also in other countries difficult to obtain. An exception is China where one can rely on GDP data at the prefecture level based on official statistical yearbooks.[20] This data allows estimating the relationship with light at a similar level of aggregation as Indian districts. However, there are some caveats when using this approach. First, light intensity is measured by various satellites over the years. These satellites can have somewhat different calibrations such that observations from different satellite years cannot directly be compared. Second, GDP data is measured within administrative boundaries and these may also change over time.[21] I therefore rely only on the year 2010 for which I have GDP figures for Chinese prefectures and the digital maps of administrative boundaries that match the units in the statistical yearbooks. This allows me to measure light and GDP on the same land area and with the same satellite, thereby addressing the two concerns above. I then regress the logarithm of GDP on the logarithm of light within Chinese prefectures in order to estimate the relationship. The

[19] The last two years have recently been made available and they have not been included in the present analysis.

[20] See Alder et al. (2013) for a more detailed description of the GDP data in the Chinese statistical yearbooks.

[21] The Chinese statistical yearbooks also report the land area. These figures show that subnational borders have indeed been changing.

estimated elasticity is 1.05 and significant, but indistinguishable from 1. In the empirical analysis, I therefore interpret the magnitude of an effect on light as an equally large effects in terms of GDP.[22] While the elasticity that is used to translate the estimate from light to GDP clearly affects the magnitude of the aggregate effects, the distributional implications are not affected by this.

1.4.2 Building a Counterfactual Highway Network for India

To replicate the Chinese network in India, I first identify the cities in India which would have been chosen by the Chinese policy and then build a counterfactual network to connect them through the Indian terrain in a way that minimizes construction costs.[23] 68 Indian cities fulfill one of the two criteria, i.e. having a population above 500,000 or being a state capital. The location of these cities is shown in Figure 1.6.

In order to determine the network which connects all targeted cities in a least-cost manner, one first needs to obtain a measure for road construction costs on the Indian terrain. I follow Faber (2013) and assume that the construction costs on a given 1x1 km cell of land depends on the slope and the share of water and built up area in the following way:

$$ConstructionCosts_c = 1 + Slope + 25 \times Builtup + 25 \times Water \tag{1.1}$$

Slope is measured in percent and *Builtup* and *Water* are binary indicators which take the unit value if the majority of the cell is built up or water, respectively.[24] Applying this formula using detailed terrain data produces a fine 1×1 km grid of construction costs for the entire Indian landscape. Given this grid of construction costs, one can in a second step apply the Dijkstra algorithm to find the cheapest connection between any two given points through the cost grid.[25] The procedure is illustrated in Figure 1.7, where the cells

[22]Note that to estimate the relationship between GDP and light I do not exploit time variation. An alternative, which has also been used in Henderson et al. (2012), is to estimate the relationship in a panel or in long differences. In the period from 2000 to 2009, the result for the later suggests an elasticity of roughly 0.5. However, it is subject to the two concerned raised above and in this context I prefer to rely on the estimate based on the 2010 cross section.

[23]This approach has previously been applied by Faber (2013) in China to construct an instrument for the actually built expressways. In the steps below, I adapt this approach to replicate the Chinese network in India.

[24]The implication of this formulation is that a 25 percentage points increase in slope raises the road construction costs in the same way as when the road has to be built through an area with existing houses, other infrastructure, or water. Different from Faber (2013), my formulation does not include wetlands.

[25]This algorithm is implemented in the ArcGIS Network Analyst extension. The same algorithm can be used to compute the least-cost transport route (instead of least cost construction path). The algorithm has already been widely used in the economics literature, for example in Dell (2012), Faber (2013), Donaldson and Hornbeck (2013), and Donaldson (forthcoming).

represent different construction costs (based on Equation 1.1) and the lines are the least-cost paths to connect the cities (shown as circles). The third step in order to obtain the counterfactual network is to find the cheapest possible way to connect all targeted cities to the network.[26] This is achieved by the Kruskal algorithm (Kruskal, 1956), which uses as inputs all bilateral construction costs and finds the minimal links needed to connect all cities at least once to the common network. This produces the least-cost network. Once it is determined which bilateral connections must be made, the counterfactual highways can be drawn with GIS software following the least-cost path computed above (illustrated by lines in Figure 1.7). The resulting counterfactual network is shown in Figure 1.9. It represents the cheapest way to formally fulfill the Chinese policy objective (connecting cities which have a population above 500'000 or are state capitals) in India.[27]

Despite its immediate link to the official policy objective, this minimalistic network is not one that would typically be implemented by governments. One reason is that planners would most likely complement it with additional connections between "loose ends" created by the algorithm. For example, if two cities are indirectly connected through other cities, then connecting them is redundant from the perspective of the policy objective, even if the cities are close to each other. However, in reality, the additional link may possibly be effective for reducing transport times. This illustrates that the least-cost network is not minimizing transport costs nor maximizing aggregate income. However, the least-cost network is a useful benchmark for the counterfactual analysis because it improves transport infrastructure for a particular set of cities which would have been targeted by the NEN. Importantly, it is an objective way to replicate the Chinese network because the least-cost network is unique. The counterfactual network therefore allows an interesting comparison between a network that focused on the four largest economic centers (the Indian GQ) and one that connects all intermediate sized cities (the Chinese NEN). In the robustness section, I discuss the results for alternative counterfactual networks in India. In particular, I propose an alternative network exploiting that the Chinese government also specified that the targeted cities should be connected with rays out of the capital city and with horizontal and vertical corridors. These alternative networks resemble more the structure of the network which was actually built in China. The disadvantage is that they are not unique as there would be several ways to make the connections. In the main part of this paper, I will therefore focus on the least-cost network and discuss the alternatives in the robustness section.

[26]Note that the previous step computed the least-cost construction path between all bilateral pairs of cities. Most of these paths are redundant because a given city may already be connected to the network through another city.

[27]More precisely, it is the cheapest way to connect a given set of nodes with bilateral links. The procedure does not allow endogenous nodes or hubs.

1.4.3 Computing Transport Costs Through a Road Network

Transport infrastructure affects economic activity in several dimensions, such as the time it takes to move goods and people, pecuniary costs from tolls, or risks associated with the use of inadequate or overused infrastructure. I will focus on the transport times as a determinant of transport costs. Higher road quality, limited access, and more capacity are all reflected in the time it takes to move goods between two locations.

The counterfactual analysis requires information on the transport times between all pairs of Indian districts for different versions of (actual and counterfactual) transport networks. While the transport times on the current network can be derived from automated searches on applications like google maps, this is not the case for past or counterfactual networks. My approach is to use the Dijkstra algorithm that finds the shortest path (in terms of transport time) between any two locations on a digitized road network. The advantage of this approach is that the same algorithm can compute all bilateral transport times for different road networks. The required inputs (described in Section 1.4.1) are the geographically referenced roads and the transport speed on different types of roads. With these inputs, it is possible to construct a grid of India where the value of each 10×10 km cell represents the costs of traveling through this cell. These travel costs depend on the quality of the road inside of each cell, i.e. the travel costs are high if there are only roads of poor quality with low travel speeds. Such a grid of transport costs is shown in Figure 1.8. The Dijkstra algorithm then calculates the cheapest way to travel from one location (district centroids, represented by dots in Figure 1.8) to another location. Depending on the road infrastructure and thus on the transport costs in each cell, the cheapest path may not be the shortest in terms of distance. More importantly, the transport times associated with the cheapest path change when the infrastructure is improved, thus generating time variation in the transport costs. Following Roberts et al. (2012), I assume that there are economies of scale in transport, such that transport costs increase less than proportionally in transport times.[28] More precisely, I calculate transport costs between an origin o and a destination d as

$$TransportCosts_{od} = 1 + TransportTime_{od}^{0.6}, \tag{1.2}$$

where the exponent of 0.6 is an average value that Roberts et al. (2012) derived for the Chinese network. A particular case is when $o = d$, i.e. transport costs within a district. Although a district is represented here by its centroid and the iceberg assumption in such a case implies transport costs of 1, this would not be accurate for actual Indian district

[28] This is a common assumption, see for example also Au and Henderson (2006) who assume that transport costs increase less than proportionally in *distance*.

which differ substantially in size. One solution which has been used in the literature is to normalize it to the observation with the smallest land area (Au and Henderson, 2006). I use the distance between the district centroid and the nearest district border as a measure for within-district costs and normalize all travel costs to the smallest distance in the sample.

By applying the Dijkstra algorithm to all versions of the transport networks (past, current, and counterfactual network), one can derive the bilateral trade costs of any pair of districts for each version. In the empirical analysis, this variation in trade costs over time is related to growth in income. The channel through which this relationship works is shown by the the conceptual framework in the next section, which serves as guide for the empirical analysis.

1.5 Conceptual Framework

This section first presents a conceptual framework that illustrates how transport infrastructure affects economic development.[29] Then I discuss how the light data and the transport networks presented in Sections 1.3 and 1.4 are used to estimate this effect. The setup is a general equilibrium trade model as in Eaton and Kortum (2002). Donaldson and Hornbeck (2013) derive from a variation of that model a reduced form expression for the impact of transport infrastructure on income. That expression captures the "market access" of a location, which is the sum over trading partners' income, discounted by the bilateral trade costs and by the market access of the trading partners. They use this framework to estimate the effect of the expansion of the American railway network on land prices. I follow this approach to estimate the effect of the Indian transport network on income by adapting their framework to a version which can be estimated with light data as a measure for real income.

1.5.1 A Ricardian Model of Trade

The basic setup is a Ricardian trade model with the immobile production factors land and labor and the mobile factor capital.[30] The economy consists of many trading regions (i.e. Indian districts), where the origin of a trade is denoted by o and the destination by d. Each district produces varieties indexed by j with a Cobb-Douglas technology using

[29]The presentation in this section focuses on the key aspects of the model. The details are discussed in the appendix.

[30]Donaldson and Hornbeck (2013) assume that labor is mobile. The motivation for and implication of the assumption that labor is immobile will be discussed below.

land (L), labor (H), and capital (K),

$$x_o(j) = z_o(j)\big(L_o(j)\big)^{\alpha}\big(H_o(j)\big)^{\gamma}\big(K_o(j)\big)^{1-\alpha-\gamma}, \tag{1.3}$$

where $z_o(j)$ is an exogenous probabilistic productivity shifter as in Eaton and Kortum (2002).[31] The production function implies marginal costs

$$MC_o(j) = \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)} \tag{1.4}$$

where q_o is the land rental rate, w_o is the wage, and r_o is the interest rate.

Trade costs between locations o and d are modeled according to an "iceberg" assumption: for one unit of a good to arrive at its destination d, $\tau_{od} \geq 1$ units must be shipped from origin o. This implies that if a good is produced in location o and sold there at the price $p_{oo}(j)$, then it is sold in location d at the price $p_{od}(j) = \tau_{od} p_{oo}(j)$. With perfect competition, prices equal the marginal costs of producing each variety such that $p_{oo}(j) = MC_o(j)$, which implies

$$p_{od} = \tau_{od} MC_o(j) = \tau_{od}\frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)} \tag{1.5}$$

$$z_o(j) = \tau_{od}\frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{p_{od}}. \tag{1.6}$$

Consumers have CES preferences and search for the cheapest price of each variety (including trade costs), such that prices in each district are governed by the productivity distribution across districts. Eaton and Kortum (2002) show that this implies a CES price index of the following form:[32]

$$P_d = \gamma\Big(\sum_o \big[T_o\big(\tau_{od} q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}\big)^{-\theta}\big]\Big)^{-\frac{1}{\theta}}. \tag{1.7}$$

I follow the notation in Donaldson and Hornbeck (2013) and define the sum over origins' factor costs as "consumer market access", because it measures district d's access to cheap

[31] Each district draws its productivity $z_o(j)$ from a Fréchet distribution with CDF $F_o(z) = Pr[Z_o \leq z] = \exp(-T_o z^{-\theta})$ where $\theta > 1$ governs the variation of productivity within districts (comparative advantage) and T_o is a district's state of technology (absolute advantage).

[32] Using the fact that the rental rate for capital is equalized everywhere to $r_o = r$, we can define the constant $\kappa \equiv \gamma^{-\theta} r^{-(1-\alpha-\gamma)\theta}$ where $\gamma = \left[\Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)\right]^{\frac{1}{1-\sigma}}$ and Γ is the gamma function.

goods,

$$\begin{aligned} P_d^{-\theta} &= \kappa \sum_o \left[T_o \big(\tau_{od} q_o^{\alpha} w_o^{\gamma} \big)^{-\theta} \right] \\ &\equiv CMA_d. \end{aligned} \tag{1.8}$$

This equation provides a relationship between prices and consumer market access, which will be exploited below to derive real income.

1.5.2 Trade Flows and Gravity

Eaton and Kortum (2002) show that the fraction of expenditures of district d on goods from district o is

$$\frac{X_{od}}{X_d} = \frac{T_o \big(q_o^{\alpha} w_o^{\gamma} \big)^{-\theta} \tau_{od}^{-\theta}}{\sum_o \left[T_o \big(q_o^{\alpha} w_o^{\gamma} \big)^{-\theta} \tau_{od}^{-\theta} \right]}. \tag{1.9}$$

Assuming that a district's expenditure equals income ($X_d = Y_d$),[33] this can be rearranged to

$$\begin{aligned} X_{od} = & \underbrace{T_o \big(q_o^{\alpha} w_o^{\gamma} \big)^{-\theta}}_{\text{Origin's productivity and factor costs}} \times \underbrace{\tau_{od}^{-\theta}}_{\text{Trade costs}} \times \underbrace{Y_d}_{\text{Destination's income}} \\ & \times \underbrace{\kappa CMA_d^{-1}}_{\text{Destination's CMA}}. \end{aligned} \tag{1.10}$$

This is a gravity equation where the amount of trade from o to d depends positively on the origin's competitiveness (productivity) and the destination's income, but negatively on the consumer market access of the destination and on the bilateral trade costs. Summing the gravity equation over destinations d yields total income of origin o,

$$Y_o = \sum_d X_{od} = \kappa T_o (q_o^{\alpha} w_o^{\gamma})^{-\theta} \sum_d \left[\tau_{od}^{-\theta} CMA_d^{-1} Y_d \right], \tag{1.11}$$

where Donaldson and Hornbeck (2013) define "firm market access" of district o as

$$FMA_o \equiv \sum_d \tau_{od}^{-\theta} CMA_d^{-1} Y_d. \tag{1.12}$$

[33]Capital is a mobile production factor such that output and expenditure could actually differ within districts. Since I cannot distinguish the two in the data, I assume that capital income is spent where it is used for production which implies that expenditure equals income.

If trade costs are symmetric, then a solution must satisfy $CMA_o = FMA_o$. Donaldson and Hornbeck (2013) refer to this term as "market access" (MA),

$$MA_o = \sum_d \tau_{od}^{-\theta} MA_d^{-1} Y_d. \tag{1.13}$$

Equation (1.11) for income then becomes

$$Y_o = \kappa T_o (q_o^\alpha w_o^\gamma)^{-\theta} MA_o. \tag{1.14}$$

Equations (1.13) and (1.14) summarize how trade costs affect income. While Equation (1.14) provides a relationship between income and market access, Equation (1.13) shows that this market access measure is the channel through which transport costs affect income. This framework resembles a gravity equation in the sense that locations which are better connected influence each other more and the influence is increasing in the size of their markets. This feature is shared by models in the new economic geography literature (see Fujita et al., 1999) and has found strong support in the data. A second appealing property of the model is that it is a general equilibrium setup and thus allows to quantify aggregate effects. In particular, the market access approach takes into account that a reduction in bilateral trade costs τ_{di} between two trading partners d and i can affect market access in o. This can be seen in Equation 1.13, where an increase in MA_d (due to a decrease in τ_{di}) reduces MA_o.

1.5.3 Empirical Implementation

The framework summarized by Equations (1.13) and (1.14) suggests a relationship between transport costs and income that can be estimated with the appropriate data. To this aim, I rewrite the model in terms of real income (which can be measured by light in each district) and I use an appropriate identification strategy to estimate the causal effect of market access on income.

Market Access

In order to incorporate luminosity as a measure for real income, I use the property in Eaton and Kortum (2002) that the price index is related to market access in the form

$$P_d = MA_d^{-\frac{1}{\theta}}. \tag{1.15}$$

This allows rewriting Equation (1.13) as

$$MA_o = \sum_d \tau_{od}^{-\theta} MA_d^{\frac{-(1+\theta)}{\theta}} Y_d^r, \tag{1.16}$$

where $Y_d^r = \frac{Y_o}{P_o}$ denotes real income. For given income (measured by light), bilateral transport costs (computed from the transport network), and trade elasticity θ (taken from Donaldson, forthcoming), I solve this system of non-linear equations and obtain each districts market access measure.[34]

Real Income

Equation (1.14) can be written in terms of real income. The wage and land rental rates can be substituted with the factor income shares to obtain

$$Y_o^r = \left(\kappa T_o\right)^{\frac{1}{1+\theta\alpha+\theta\gamma}} \left(\frac{\alpha}{L_o}\right)^{\frac{-\theta\alpha}{1+\theta\alpha+\theta\gamma}} \left(\frac{\gamma}{H_o}\right)^{\frac{-\theta\gamma}{1+\theta\alpha+\theta\gamma}} \left(MA_o\right)^{\frac{1+\theta(1+\alpha+\gamma)}{(1+\theta\alpha+\theta\gamma)\theta}}. \tag{1.17}$$

Estimating this equation in a cross-section would require to control for relevant district characteristics which are difficult to obtain. It is therefore useful to exploit the panel structure to identify the causal relationship. Therefore, the above equation will be estimated with a fixed effect panel regression that relies on the time variation within districts. This allows accounting for the unobserved heterogeneity across districts. Equation (1.18) shows the analogue of Equation (1.17) in logs and over time:

$$\begin{aligned} \ln\left(Y_{o,t}^r\right) &= \underbrace{-\frac{\theta\alpha}{1+\theta\alpha+\theta\gamma}\ln\left(\frac{\alpha}{L_o}\right) - \frac{\theta\gamma}{1+\theta\alpha+\theta\gamma}\ln\left(\frac{\gamma}{H_o}\right)}_{\text{Constant over time}} \\ &+ \underbrace{\frac{1}{1+\theta\alpha+\theta\gamma}\ln\left(\kappa_t\right)}_{\text{Country characteristics}} + \underbrace{\frac{1}{1+\theta\alpha+\theta\gamma}\ln\left(T_{o,t}\right)}_{\text{Productivity}} \\ &+ \underbrace{\frac{1+\theta(1+\alpha+\gamma)}{(1+\theta\alpha+\theta\gamma)\theta}\ln(MA_{o,t})}_{\text{Market access}}. \end{aligned} \tag{1.18}$$

Time variation in real income is measured by light in the years 2000 (the year before the NHDP started) and 2009. Variation in the market access measures, obtained from solving Equation (1.16), can either be due to changes in the transport infrastructure (differences

[34] Donaldson and Hornbeck (2013) estimate the effect of market access on land values. They measure market access with population and their benchmark estimation uses a first order approximation $MA_o \approx \sum_d \tau_{od}^{-\theta} N^d$, where N denotes population. They compare their results to those based on the numerical solution for MA implied by the model and find similar effects (Column 2 in their Table 1). I focus on the second approach and use the market access measures based on the numerical solution of Equation (1.16).

in the bilateral transport costs τ_{od}) or in income. The corresponding panel fixed effects specification is

$$\ln(light_{o,s,t}) \quad = \quad \phi_o + \delta_{s,t} + \beta \ln\left(MA_{o,t}\right) + \varepsilon_{o,s,t}, \tag{1.19}$$

where ϕ_o is a location fixed effect and $\delta_{s,t}$ is a state-year fixed effect.[35] The link to Equation (1.18) is as follows. The first line in Equation (1.18) collects parameters and factor endowments, which are assumed to be constant over time and are thus absorbed by the location fixed effects ϕ_o. The second line includes country characteristics (the interest rate inside of κ) and productivity of each district. While changes in the national interest rate are absorbed by the state-year fixed effects, local productivity can potentially vary over time *and* districts. As will be argued below, my identification strategy uses exogenous variation in transport infrastructure such that there is no effect of unobserved productivity changes on transport infrastructure. Furthermore, part of this variation is absorbed by the state-year fixed effects. The last line in Equation (1.18) shows the effect of market access, which is computed in Equation (1.16) for different transport infrastructures.

A caveat of the specification in Equation (1.19) is that the state-time fixed effects may absorb differences in the growth rates across states that could be driven by some states being more exposed to infrastructure investments. As an alternative specification, I will also report the results for the case when the state-year fixed effects are replaced by predetermined state-characteristics such as state-level growth trends prior to the start of the NHDP.

The model predicts an elasticity of real income with respect to market access of

$$\beta = \frac{1 + \theta(1 + \alpha + \gamma)}{(1 + \theta\alpha + \theta\gamma)\theta}. \tag{1.20}$$

While I identify only β and cannot estimate the individual parameters separately, one can verify whether the resulting estimate for β is close to what would be predicted by certain parameter values. Using 0.3 for the capital share (and therefore 0.7 for the sum of the land and labor shares) and 3.8 for the trade elasticity would imply an elasticity of income with respect to market access of 0.54. This value is not rejected by the estimates in Section 1.6.

Model and Data

The data required for the estimation of Equation (1.19) are income of each district (obtained from light data) and bilateral trade costs (computed based on a shortest path

[35] State is an administrative unit above districts.

algorithm). I consider the period from 2000 to 2009 in order to capture the infrastructure investments of the NHDP, which started in 2001. The GQ and NS-EW were built in different phases during which fragments of new or upgraded highways were added to the network. I abstract from the yearly variation and only consider the total constructions between 2000 and 2009. Using data for the years 2000 and 2009, Equation (1.19) can be estimated in first differences. For the computation of the market access measures in Equation (1.16), a value for the trade elasticity θ is assumed. Ideally this would be estimated with bilateral trade data between Indian districts. While I am not aware of an estimate for the trade elasticity for contemporaneous India, Donaldson (forthcoming) has estimated θ using bilateral trade data between Indian districts for his study on the colonial railway system and I use his estimate of 3.8. This estimate is also in line with recent results by Simonovska and Waugh (2013) using international trade data.

Identification

Identifying the causal effect of infrastructure on income is challenging for several reasons. First, the choice of where to build infrastructure is not exogenous. In particular, the GQ had the explicit goal of connecting the four largest economic centers. This raises the concern that infrastructure may have been built where high growth was expected. But the clear objective of the GQ also poses an advantage for identification. By connecting the four largest centers with fairly straight lines, it affected districts which happened to be in between two important cities. By excluding the nodes of a network, it is therefore possible to exploit plausibly exogenous variation in transport infrastructure in districts which were accidentally affected by the GQ. This identification strategy was proposed by Chandra and Thompson (2000) and Michaels (2008) and similar strategies have been applied to China and India by Banerjee et al. (2012), Datta (2012), and Ghani et al. (2012). I follow this strategy and exclude the nodal cities and the corresponding states Maharashtra, Delhi, West Bengal, and Tamil Nadu.

A second challenge to identification is that shocks to income may be spatially correlated. Since the market access of o sums over incomes of trading partners d and a spatially correlated income shock may affect both o and d, changes in market access over time are likely to be correlated with o's own income. Therefore, an observed correlation between income and market access can arise even if there was no change in trade costs. To address this, I hold income fixed in 2000 when computing market access and exploit only the variation due to changes in transport infrastructure (and thus bilateral trade costs), as is shown in Equation (1.21),

$$MA_{o,t} = \sum_d \tau_{od,t}^{-\theta} MA_{d,t}^{\frac{-(1+\theta)}{\theta}} Y_{d,2000}^r. \tag{1.21}$$

According to the model, the elasticity of income with respect to market access, β, is constant over the counterfactual. Therefore, given an identification strategy that allows to estimate this β, income can be predicted for counterfactual transport networks that imply different market access values. The results of these two steps are discussed in the next section.

1.6 Results

The results of the empirical analysis are presented in three steps. First, I estimate the elasticity of income with respect to market access based on Equation (1.18) of the model. I exploit time variation in market access due to actually built infrastructure in India. The market access measures are computed from Equation (1.21) and they capture general equilibrium effects.[36] Second, I will use the estimated elasticity to predict income levels in 2009 for various (actual and counterfactual) transport networks and assess their aggregate effects. The distributional consequences of the different transport networks are discussed in the third step.

1.6.1 Elasticity of Income with Respect to Market Access

The estimate of β in Equation (1.19) represents the elasticity of income with respect to market access. The results from estimating β based on the time variation in market access due to the construction of the GQ and parts of the NS-EW between 2000 and 2009 are shown in Table 1.2. As a benchmark, column 1 uses the full sample of mainland Indian districts and regresses the logarithm of income on the logarithm of market access, controlling for district fixed effects and state-year fixed effects. The estimated coefficient implies that a one percent increase in market access is associated with a 0.39 percent increase in income. For the subsequent counterfactual exercise, it is crucial to estimate the causal effect of market access on income. In particular, one has to address concerns related to omitted variables and reversed causality. I first discuss how I address omitted variables in the context of column 1 of Table 1.2 and then turn to the problem of reverse causality (addressed in column 2).

The problem of omitted variables can be mitigated by the panel structure of the data.[37]

[36] The results are similar when using Equation (1.21) to instrument Equation (1.16).

[37] This is an important advantage over a cross-sectional analysis, where unobservable location characteristics would likely be correlated both with income and transport infrastructure. An example for this issue is the economic or political situation in a state or district, which may determine whether (and how effectively) investments in roads are made. The same characteristics may also affect the economic performance through the overall investment climate or other government actions. As it is difficult to control for all relevant location characteristics, transport infrastructure could be correlated with the error term

More precisely, the inclusion of district fixed effects in the panel estimation in column 1 absorbs all time-invariant district characteristics such as the initial level of development. The estimation only exploits the changes in income and in transport infrastructure over time. Although in principal it could also be that there are time-varying district characteristics (for example economic or political shocks) that affect *changes* in income, it is less likely – given the national scope of the NHDP – that such shocks would also affect the transport network. Furthermore, time-varying heterogeneity at a higher level of aggregation is absorbed by state-year fixed effects which allow for differences in states' growth trends.

A second source of endogeneity is due to reverse causality of economic performance on transport infrastructure. As mentioned in the discussion of the identification strategy in Section 1.5, it is evident that the GQ was not built randomly, but targeted the four nodal cities Delhi, Calcutta, Chennai, and Mumbai. It is possible that the choice of this network structure was driven by the economic performance (or the anticipation of which) in these regions. Following the identification strategy by Chandra and Thompson (2000) and Michaels (2008), I exclude the nodal states and only exploit the variation in districts that were in between these nodes and therefore accidentally affected by the roads connecting the four largest centers. This identification strategy is exploited in column 2, which re-estimates the specification of column 1 for the sub-sample of non-nodal districts. The point estimate changes only marginally to 0.395 and continues to be significant at 5 percent. This suggests that the observed correlation between market access and income is not driven by the endogenous location of infrastructure.[38]

The first two specifications include state-year fixed effects to control for potential differences in the time trends across states. The identification therefore comes from variation in districts over time and within states. The inclusion of the state-year fixed effects implies that cross-state differences in the growth rates from 2000 to 2009 are absorbed. This could be a concern if these differences are related to changes in the transport infrastructure during this period, such that part of the effect of transport infrastructure may be attributed to the state-year fixed effect instead of to an increase in market access. This is a likely scenario, since some states experienced larger average reductions in travel costs than others and may have had higher growth for this reason. Furthermore, the estimated fixed effects are unlikely to be constant over the counterfactual networks. An alternative approach would be to find controls for district trends which are independent of the road

in a cross-sectional analysis.

[38]Further evidence against the concern that the location of transport infrastructure is driven by economic performance is provided in the robustness section. There, I show that changes in transport infrastructure between 2000 and 2009 are uncorrelated with districts' growth trends prior to the start of the NHDP.

investments. Since the light data goes back to 1992, it is possible to include the pre-2000 growth in light to capture state-specific trends prior to the road investment program. I also include initial levels of light and the shares of services and industry in state income.[39] As column 3 shows for the full sample, when the state-year fixed effects are replaced with the state-level control variables, then the point estimate increases to 0.537 and continues to be statistically significant at the 5 percent level. In column 4, I re-estimate the specification of column 3 for the sub-sample of non-nodal states and find a similar estimate of 0.574.

For the counterfactual exercise, I rely on the sub-sample of non-nodal districts to estimate the causal effect of market access on income. I therefore report the results of the counterfactual exercise based on the estimates of columns 2 (state fixed effects) and 4 (state controls). Each of the two specifications has its advantages and the two estimates provide a credible range for the true effect. Column 2 appears to be the more conservative specification to estimate β since it absorbs the state-level effects of roads. I therefore view this estimate as a lower bound. Column 4 provides an alternative for controlling for state trends and its estimate for β of 0.574 is close to the elasticity predicted by the model (for a reasonable choice of parameter values). In this case the identification of the causal effect relies fully on the randomness in the treatment of non-nodal states.

1.6.2 Aggregate Effects of Transport Infrastructure

The results above established an effect of transport infrastructure on income through the channel of market access. The estimate of this effect can be used to predict each district's income for various counterfactual networks. Because market access captures the general equilibrium effects of transport infrastructure, this allows to analyze the aggregate and the distributional consequences.

Aggregate Effects of the Existing Infrastructure

In order to interpret the magnitude of the impact of a counterfactual infrastructure, I first evaluate the effect of the actually built GQ and NS-EW. To this aim, I construct a network in 2009 in the absence of the GQ and NS-EW and ask how India would have developed if the GQ and the NS-EW had not been built.[40] In the conceptual framework used here, this would imply that there was no change in the measures for market access because the

[39] More precisely, I include interactions of the year indicator with these variables, as the district fixed effects absorb the time-invariant characteristics.

[40] In order to avoid confusion with the terminology, I do not use the term "counterfactual" when considering the 2009 network without the GQ and NS-EW, although it is evidently a counterfactual network. The term "counterfactual" will only be used for the network proposed in Section 1.4.2.

actually built GQ and finished parts of the NS-EW are the only sources of variation in the road infrastructure that I consider. Based on the specification in the second column of Table 1.2, the results suggest that aggregate income in 2009 would be 3.4 percent lower if the GQ and the NS-EW had not been built. The result based on the specification with state controls instead of state fixed effects would imply an effect of 4.7 percent of income. Most of this effect is due to the GQ, which alone led to a 2.4 - 3.5 percent higher income by 2009. Aggregate GDP in India in 2009 was USD 905 billion (1999 prices) such that a 3.4 percent difference would correspond to roughly USD 31 billion.[41]

Aggregate Effects of the Counterfactual Infrastructure

In this section I ask how India would have developed if it had built a transport infrastructure like the Chinese NEN. There are two scenarios which may be considered in this context. First, I *add* a network that mimics the Chinese NEN to the Indian transport infrastructure. Given the evidence that the current transport system does not have enough capacity, this is an interesting scenario to analyze. However, the counterfactual network will create certain redundancies with the already improved infrastructure. The results based on column 2 of Table 1.2 suggest that income in 2009 would have been 2.2 percent higher if in addition to the existing infrastructure also the network discussed in Section 1.4 had been built, which translates into a USD 20 billion benefit. The increase in income amounts to 3.2 percent when the specification of column 4 of Table 1.2 is used, or USD 29 billion.

In a second scenario, I ask how India would have developed if instead of building the GQ it had chosen a similar strategy as the Chinese NEN. Therefore, I consider a highway network where the GQ is *replaced* by the network proposed in Section 1.4. The total length of the GQ is 5,846 km, while the length of the counterfactual is 12,840 km. Given this difference, it is not surprising that the aggregate effect of replacing the GQ with the counterfactual is an increase in aggregate income relative to the actual network. This increase is (based on column 2 of Table 1.2) roughly 1.5 percent of income in 2009 (USD 13 billion). The increase is 2.2 percent based on the specification with state controls, which implies a USD 20 billion benefit. Although the counterfactual network has more than twice the length of the GQ, the aggregate effects are relatively small in comparison to the 2.4 - 3.5 percent increase due to the GQ. The likely reason is that the GQ connected the four largest economic centers and could thereby generate a substantial increase in market access. However, there are important distribution consequences, which will be discussed further below.

[41]In what follows the base is omitted, but all values are in USD at 1999 prices. The costs of the investments are discussed below.

Construction Costs of the Counterfactual Infrastructure

In order to evaluate the net aggregate gain of the counterfactual networks as described above, it is necessary to compute the construction costs of the counterfactual network. The challenge is that the normalized units of Equation (1.1) do not correspond to actual monetary costs and only represent the relative increase in construction costs due to the various topographic features. In order to derive the expected costs of the counterfactual in USD, I first replicate the GQ on the cost grid discussed in Section 1.4, which yields the costs of the GQ in terms of the units in Equation (1.1). Since the actual cost of the GQ are known, one can derive the ratio between the costs in units of Equation (1.1) and the actual USD costs. This ratio then allows to predict the USD costs of the counterfactual roads by scaling the costs in Equation (1.1). Using this approach, the costs of the full counterfactual network are approximately USD 17.5 billion. However, when adding the counterfactual network to the existing network, then a number of connections are redundant because they have already been made by the GQ or NS-EW. When excluding these connections from the cost calculations, then the total costs amount to USD 14.3 billion.[42]. To compare costs and benefits, I have to make assumptions on the interest rate and on the year in which the construction costs have to be paid. For the later I assume that the costs were evenly spread over the years 2001-2009. For the real interest rate during the period 2001-2009, I take 2 percent.[43] With accumulated interests until 2009, the costs amount to USD 19 for the full network and to USD 16 billion for the network without redundancies.

Comparing these costs to the benefits suggests aggregate net gains from *adding* the counterfactual of about USD 4 billion when using state fixed effects and USD 13 billion when using state control variables. The net gains from *replacing* the GQ with the counterfactual would lie between zero and USD 7 billion.[44] Besides these gains over the first 9 years of the project, there may be higher benefits of such infrastructure projects on a longer horizon, although in that case the discount rate plays a key role and one has to consider additional costs for maintenance.

Overall, I conclude that by connecting the largest economic centers, the GQ had achieved relatively large aggregate effects at a moderate cost, i.e. there were net gains from the GQ. Taking into account the construction costs, the additional net gains of

[42]The costs of the GQ were USD 6 billion (Ghani et al., 2012), but it had less than half the length of the counterfactual.

[43]According to the Reserve Bank of India, the average nominal interest rate on central government bonds for the period 2001-2009 was 7.5 percent. However, the benefits and costs above are denoted in 1999 constant prices and the average inflation rate between 2001 and 2009 was 5.7 percent. Using, instead of an average value of 2 percent, the yearly real interest rates based on government bonds and inflation would imply costs of USD 15.3.

[44]In this case the costs of the full counterfactual network have to be paid, but USD 6 billion would have been saved on the GQ.

the counterfactual are small. However, the counterfactual network also includes the intermediate-sized cities and thereby reaches into more districts, including the less developed. This has important distributional consequences, which will be quantified below.

1.6.3 Distributional Effects of Transport Infrastructure

China and India have shown significant differences in their regional development. In particular, India had less convergences and some "lagging regions" (Chaudhuri and Ravallion, 2006). In this light, an important question is how transport infrastructure may contribute to these differences in regional development. One advantage of the approach used here is that the effects of different transport networks can be assessed both at the aggregate and at the local level, allowing to analyze the distributional consequences and the regional development patterns under each scenario. As will be shown below, the effects on the local development of Indian districts differ substantially over the various versions of the transport networks. I will start by discussing the effects of the actually implemented parts of the NHDP and then consider the effects of the two counterfactual scenarios. To be able to discuss the differences across states and districts, the analysis builds on the specification using state-level control variables (column 4 of Table 1.2) instead of state-year fixed effects.

Distributional Effects of the Existing Infrastructure

Figure 1.10 shows the estimated effects of the GQ and the finished parts of the NS-EW (the network in Figure 1.5) at the level of Indian districts. The numbers represent the percentage gains from building the GQ and finished parts of the NS-EW.[45] As expected, the effects are strongest along the paths of the newly built or upgraded highways. The largest beneficiaries had a 33 percent higher income level in 2009 than they would have had in the absence of the GQ and NS-EW. Although transport costs did not increase anywhere, there are some losers from the infrastructure investments, which is due to trade diversion.

Distributional Effects of the Counterfactual Infrastructure

Adding the counterfactual network to the existing infrastructure increases particularly the market access of regions in the center and in the east which have been neglected by the recent improvements in infrastructure. Particularly the central regions were also

[45] More precisely, the numbers correspond to differences between the prediction of income with the actual network and the prediction with the counterfactual network, relative to the prediction with the actual network.

the ones with low growth during the past decade. As there are several cities in that area which would fulfill the criteria of the NEN, they become better connected by the counterfactual network and thus experience increases in market access. The results from adding the counterfactual network to the existing infrastructure, illustrated in Figure 1.11, also show that the growth benefits are generally more equally distributed across the country compared to the existing network with the GQ and the NS-EW. The largest beneficiaries gain 32 percent of income, but there are also some districts with moderate losses. This is purely due to trade diversion, since trade costs do not increase anywhere when transport infrastructure is added.

When replacing the GQ with the counterfactual network, then the above results in terms of distribution are strengthened and the largest beneficiaries are still regions with low growth during the past decade (Figure 1.12). But in this scenario, there are also significant losses because, by replacing the GQ with an alternative network, those cities which were well connected by the GQ have higher (or at best the same) trade costs. In particular, the four large cities which were targeted by the GQ experience declines. The largest beneficiaries have gains of up to 36.8% and the largest loss is 17.4%.

Planned Highway Projects and Policy Implications

The above evidence on the impact of transport infrastructure makes clear that there are both aggregate and distributional consequences. By choosing a network that connects the four largest economic centers, India has been able to achieve an increase in income that is well above the construction costs of the new or upgraded highways. However, the strategy also implied that lagging regions were largely neglected by the new infrastructure investments. These distributional consequences are particularly relevant in view of the unequal regional development of India. Policy makers seem to be aware of this and the NHDP did include plans for other highway connections besides the GQ that reach into more states. In particular, the government planned the North-South and East-West Corridors which cross through regions that were not reached by the GQ. However, these other projects were delayed and by 2009 only a small part has been finished (see also Ghani et al, 2012). A complementary exercise is therefore to compare the effects which could be expected from completing the planned corridors to the effects from the counterfactual network that follows the Chinese strategy. The results suggest that the counterfactual network generates about 1 percent higher income than the completion of the NS-EW corridors. Clearly, districts along the planned but not yet implemented routes reap larger gains from these corridors than from the counterfactual. There are therefore losers if instead of the planned NS-EW corridors a network with Chinese characteristics is built. But, as is shown in Figure 1.13, the counterfactual network reaches more regions and especially parts of the country that have experienced low growth rates.

1.7 Robustness

The results presented so far rely on a particular counterfactual network (the least-cost network), Furthermore, I had to make a number of assumptions to estimate the effect of transport infrastructure and to perform the counterfactual analysis. This section first presents the results for further counterfactual networks and then discusses robustness to pre-investment trends, weighting, and alternative choices for parameter values.

1.7.1 Alternative Counterfactual Highway Networks

The least-cost network presented in Section 1.4 implements the cheapest network that connects with bilateral links the cities which would fulfill the criteria of the Chinese NEN. The advantage of this network is that it represents an objective way to replicate the Chinese policy. The disadvantage is that it has some features that we do not observe in reality. In particular, there are some cities which are relatively close but not directly connected. The reason for this is that the Kruskal algorithm has as its only objective to connect all cities in the cheapest way. It does not take into account that a connection between two cities which are already part of the network could be made in order to further reduce transport costs. This is particularly evident when considering the "loose ends" in Figure 1.9.

In order to evaluate the effect of networks that are closer to those we observe in reality, I construct two alternative counterfactual networks. I first "close" the network of Figure 1.9 by adding connections between the loose ends. This network is shown in Figure 1.14. The results suggest that replacing the GQ with this counterfactual network would increase income by 1.9 - 2.8 percent, roughly 0.5 percentage points more than the least-cost network. For a second counterfactual network, I exploit that the Chinese policy not only specified which types of cities should be connected, but also how (World Bank, 2007b). More precisely, the policy stated that the cities with a population above 500,000 and state capitals should be connected in a network that consists of rays spreading out from the capital city Beijing and with horizontal and vertical corridors. I apply this approach to India by connecting the targeted cities with rays from Delhi and horizontal and vertical connections, while the precise routes of these connections are again determined by the terrain. I follow the rough rule that the number of connections should be proportional to the total land area of the two countries, thus making about three times fewer rays and corridors in India than in China. The resulting network is illustrated in Figure 1.15. This network resembles the actually built NEN and is significantly denser than the least-cost network proposed in Section 1.4. It is therefore not surprising that this network generates large gains when replacing the GQ. The estimated effects are between 3.3 and 4.9 percent. The gains correspond to between USD 30 and 44 billion, while the estimated construction costs of this network amount to USD 31 billion.[46] This result is consistent with the finding for the least-cost network that there may be some net gains but that they are not necessarily large. However, the maybe more important implication is again due to the distributional effect. As is shown in Figure 1.16, some of the largest gains are precisely in those regions which previously experienced low growth.

1.7.2 Trends in District Growth Prior to Road Investment

The identification strategy used in Section 1.6 relied on the assumption that non-nodal districts were randomly affected by the GQ that connected the four largest economic centers. One may have the concern that the structure of the GQ was chosen precisely because it goes through certain targeted but non-nodal regions. One hypothesis could be that the GQ was planned such that it goes through regions that were already growing fast. Since the light data goes back to 1992 and the NHDP started after 2000, it is possible to test whether districts' growth rates prior to the NHDP are related to the subsequent reduction in travel costs due to new roads. To this aim, I estimate the specifications of columns 2 and 4 of Table 1.2 for non-nodal states but use as the dependent variable the growth in light between 1992 and 1999. If it was the case that transport infrastructure was improved precisely in those districts that were already growing fast, then we should observe a positive correlation between increases in market access due to the GQ and the growth rate prior to its construction. The results are shown in Table 1.3. In neither of the two specifications is the estimate significant. Furthermore, the point estimate is in both cases substantially lower than the ones in Table 1.2 or even negative. This provides compelling evidence against the hypothesis that the GQ connected non-nodal districts that were already growing faster.

1.7.3 Weighting by Initial Income

A further concern may be that the results presented so far are driven by districts with little initial light, because small absolute changes in light in these districts may generate large growth rates. Although it is not evident that smaller districts should be given less weight, one may worry that their measurement error is larger. Table 1.4 repeats the regressions of Table 1.2 but weights observations by the logarithm of initial light in 2000. While not

[46] I again assume that the costs were evenly spread over the 9 years and I use an average annual real interest rate of 2 percent.

being more precise, the estimates are of lower magnitude when weighting by initial light. Using these estimates for the counterfactual analysis yields somewhat smaller aggregate effects, but does not change the distributional implications of the different transport networks.

1.7.4 Alternative Values for the Trade Elasticity

When solving the system of equations in (1.21) numerically to derive the market access measures, it was necessary to make a choice for the trade elasticity parameter θ. The value of 3.8 was chosen based on Donaldson (forthcoming) who estimated the trade elasticity using bilateral trade data between Indian districts during the colonial time. Although not estimated from current trade data, this estimate is in line with recent evidence by Simonovska and Waugh (2013). Other estimates in the literature tend to be higher. Therefore, Tables 1.5 - 1.7 report the estimated effect of market access on income with values for the trade elasticity θ of 3, 5, and 7. The point estimates for the preferred specifications in columns 3 and 4 range from 0.41 to 0.65. With one exception (column 4 in Table 1.5), the estimates are significant at the 10 percent level. The preceding analysis in Section 1.6, by using a value of 3.8 for the trade elasticity, estimated the effect of income with respect to market access around 0.54 or 0.57. These appear to be intermediate values compared to the estimates from the various alternative θ.

1.7.5 Light per Capita

In the conceptual framework and in the empirical analysis so far, I have abstracted from changes in population across districts that may lead to changes in income per capita. In a further robustness check, I therefore use census data on population size in each district in 2001 and 2011 in order to estimate the effect on light per capita.[47] The decadal growth rates of light per capita across mainland Indian districts are shown in Figure 1.17. The elasticities of income per capita with respect to market access (using the baseline specification in Table 1.2) are shown in Table 1.8. The estimates suggest that the result is similar when using aggregate or per capita figures. For example, the fixed effects regression without nodal states (column 2) suggests a small increase in the point estimate from 0.395 to 0.408 and the standard errors are also relatively similar.

[47] Data collection for the 2011 census began in 2010. Although there is still a small discrepancy to the period for the light data (2000 to 2009), it is unlikely that this would change the results substantially.

1.8 Conclusion

Investments in transport infrastructure are often at the heart of efforts to foster economic development, as it is generally agreed that insufficient transport infrastructure is a key constraint in many countries. However, the impact of these investments is difficult to identify due to the general equilibrium consequences of transport networks. Furthermore, we often lack sources of exogenous variation in infrastructure, which is needed to estimate the causal effects.

This paper contributes to our understanding of the effects of transport infrastructure on development by analyzing a major Indian highway project in a general equilibrium trade model. I combine the theoretical framework with satellite data and geographically referenced information to measure income, terrain features, and road infrastructure at a high spatial resolution. The integration of precise geographic data and economic theory allows me to perform detailed counterfactual analyses. The findings suggest that the recent Indian highway investments led to positive aggregate net gains, but unequal effects across districts. A comparison to a counterfactual network that connects intermediate-sized cities shows modest aggregate effects relative to the actual network. However, there are important distributional effects. In particular, previously less developed regions would benefit substantially from such a network that integrates regions of intermediate density. The results of this counterfactual stand in stark contrast to the ones of the actual highway investments in India, which have focused on connecting the four largest economic centers. The comparison of the regional development effects under the actual and counterfactual networks therefore provides an explanation for the lack of convergence by India's lagging regions.

The implications of the findings above extend to other countries. The theoretical framework allows to quantify the aggregate and distributional effects and I find that particularly the later are sizable. This suggests that the debates about infrastructure investments in other countries should give careful consideration to the distributional consequences of alternative networks. Data on geographic and economic characteristics based on high-resolution satellite images is commonly available. Therefore – with the methods applied in this paper – the effects of infrastructure projects could be evaluated in many other settings.

The possibilities from integrating economic theory with geographic data also raise interesting new questions. For example, it would be fascinating to identify the optimal network with respect to policy objectives such as aggregate income or distributional goals. There could also be important interactions of regional economic policies with the transport network. Since infrastructure investments are often tied to economic policy, it would be important to consider them jointly for the policy analysis. Finally, the decision of how to invest in transport infrastructure can hardly be separated from environmental considerations. This connection is apparent in many policy debates and there may be tradeoffs between different objectives. The present paper contributes to this debate by quantifying the economic impact of transport infrastructure and thereby providing a sound basis for a more general assessment.

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1.10 Tables

Table 1.1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Sum of light 2000	17884.53	18965.65	0	138936.5	590
Mean light intensity 2000	4.35	6.52	0	62.91	590
Sum of light 2009	19552.13	22124.29	0	151527	590
Mean light intensity 2009	4.89	7.41	0	63	590
Within-sat yearly growth rate	0.03	0.11	-0.22	1.85	588
District area (km2)	5329.64	4676.99	18	47855	590

The table shows the summary statistics of the light data. Sum of light is the total light measured within a district's boundaries. Mean light intensity is light per pixel. The within-satellite yearly growth rate from 2000 to 2009 is reported to address differences in satellite calibration. This figure is the average growth rate when only growth observations from the same satellite are used. The total sample consists of 590 Indian mainland districts.

Table 1.2: Income and Actual Transport Infrastructure Investments

	(1)	(2)	(3)	(4)
Log Market Access	0.392**	0.395**	0.537**	0.574**
	(2.58)	(2.36)	(2.54)	(2.29)
Excluding nodal states	No	Yes	No	Yes
State-year fixed effects/State controls	FE	FE	State controls	State controls
District fixed effects	Yes	Yes	Yes	Yes
N	585	501	582	498
R2	0.497	0.492	0.212	0.209

The table shows the elasticity of income with respect to market access (based on within-variation). The dependent variable is the logarithm of the sum of light in each district in the years 2000 and 2009. The explanatory variable is market access computed based on Equation (1.21). All regressions include district fixed effects. Columns 1 and 2 include state-year fixed effects. In columns 3 and 4 the state-year fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). T-statistics are shown in brackets. Standard errors are clustered at the state-level.

Table 1.3: Income Prior to Road Investments

	(1)	(2)
Log Market Access	0.128	-0.0834
	(0.43)	(-0.33)
Excluding nodal states	Yes	Yes
State-year fixed effects/State controls	FE	State controls
N	489	486
R2	0.412	0.232

The table shows the results from regressing districts' income growth between 1992 and 1999 on changes in market access between 2000 and 2009. Column 1 includes state fixed effects. In column 2 the state fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). T-statistics are shown in brackets. Standard errors are clustered at the state-level.

Table 1.4: Income and Actual Transport Infrastructure Investments when Weighting by Initial Light

	(1)	(2)	(3)	(4)
Log Market Access	0.282***	0.268**	0.385**	0.391*
	(2.88)	(2.57)	(2.36)	(1.91)
Excluding nodal states	No	Yes	No	Yes
State-year fixed effects/State controls	FE	FE	State controls	State controls
District fixed effects	Yes	Yes	Yes	Yes
N	585	501	582	498
R2	0.520	0.515	0.212	0.206

The table shows the elasticity of income with respect to market access (based on within-variation). The dependent variable is the logarithm of the sum of light in each district in the years 2000 and 2009. The explanatory variable is market access computed based on Equation (1.21) with a trade elasticity (θ) of 3.8. All regressions include district fixed effects (not shown). Columns 1 and 2 include state-year fixed effects. In columns 3 and 4 the state-year fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). Observations are weighted by the log of districts' light in 2000. T-statistics are shown in brackets. Standard errors are clustered at the state-level.

Table 1.5: Income and Actual Transport Infrastructure Investments with Trade Elasticity (θ) of 3

	(1)	(2)	(3)	(4)
Log Market Access ($\theta = 3$)	0.297**	0.277**	0.414*	0.416
	(2.61)	(2.27)	(1.85)	(1.54)
Excluding nodal states	No	Yes	No	Yes
State-year fixed effects/State controls	FE	FE	State controls	State controls
District fixed effects	Yes	Yes	Yes	Yes
N	585	501	582	498
R2	0.493	0.488	0.204	0.201

The table shows the elasticity of income with respect to market access (based on within-variation). The dependent variable is the logarithm of the sum of light in each district in the years 2000 and 2009. The explanatory variable is market access computed based on Equation (1.21) with a trade elasticity (θ) of 3. All regressions include district fixed effects (not shown). Columns 1 and 2 include state-year fixed effects. In columns 3 and 4 the state-year fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). Observations are weighted by the log of districts' light in 2000. T-statistics are shown in brackets. Standard errors are clustered at the state-level.

Table 1.6: Income and Actual Transport Infrastructure Investments with Trade Elasticity (θ) of 5

	(1)	(2)	(3)	(4)
Log Market Access ($\theta = 5$)	0.453**	0.464**	0.598***	0.648***
	(2.70)	(2.54)	(3.00)	(2.82)
Excluding nodal states	No	Yes	No	Yes
State-year fixed effects/State controls	FE	FE	State controls	State controls
District fixed effects	Yes	Yes	Yes	Yes
N	585	501	582	498
R2	0.499	0.494	0.213	0.212

The table shows the elasticity of income with respect to market access (based on within-variation). The dependent variable is the logarithm of the sum of light in each district in the years 2000 and 2009. The explanatory variable is market access computed based on Equation (1.21) with a trade elasticity (θ) of 5. All regressions include district fixed effects (not shown). Columns 1 and 2 include state-year fixed effects. In columns 3 and 4 the state-year fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). Observations are weighted by the log of districts' light in 2000. T-statistics are shown in brackets. Standard errors are clustered at the state-level.

Table 1.7: Income and Actual Transport Infrastructure Investments with Trade Elasticity (θ) of 7

	(1)	(2)	(3)	(4)
Log Market Access ($\theta = 7$)	0.413***	0.422***	0.501***	0.531***
	(3.08)	(2.98)	(4.67)	(4.52)
Excluding nodal states	No	Yes	No	Yes
State-year fixed effects/State controls	FE	FE	State controls	State controls
District fixed effects	Yes	Yes	Yes	Yes
N	585	501	582	498
R2	0.495	0.491	0.205	0.203

The table shows the elasticity of income with respect to market access (based on within-variation). The dependent variable is the logarithm of the sum of light in each district in the years 2000 and 2009. The explanatory variable is market access computed based on Equation (1.21) with a trade elasticity (θ) of 7. All regressions include district fixed effects (not shown). Columns 1 and 2 include state-year fixed effects. In columns 3 and 4 the state-year fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). Observations are weighted by the log of districts' light in 2000. T-statistics are shown in brackets. Standard errors are clustered at the state-level.

Table 1.8: Income per Capita and Actual Transport Infrastructure Investments

	(1)	(2)	(3)	(4)
Log Market Access	0.398**	0.408**	0.485**	0.520*
	(2.37)	(2.20)	(2.20)	(2.01)
Excluding nodal states	No	Yes	No	Yes
State-year fixed effects/State controls	FE	FE	State controls	State controls
District fixed effects	Yes	Yes	Yes	Yes
N	584	500	582	498
R2	0.505	0.502	0.222	0.223

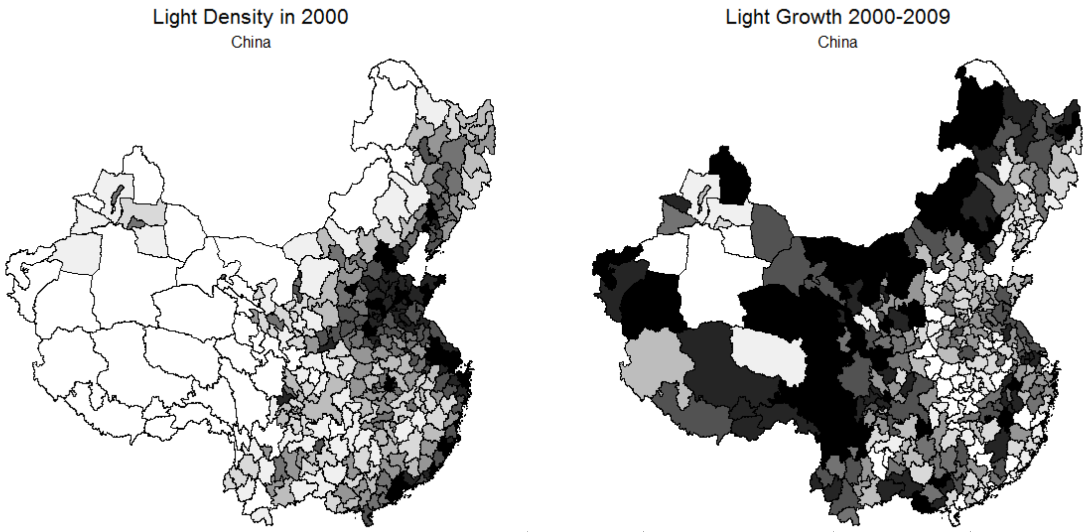
The table shows the elasticity of income per capita with respect to market access (based on within-variation). The dependent variable is the logarithm of the sum of light in each district in the years 2000 and 2009 relative to the population size in 2001 and 2011. The explanatory variable is market access computed based on Equation (1.21). All regressions include district fixed effects. Columns 1 and 2 include state-year fixed effects. In columns 3 and 4 the state-year fixed effects are replaced by a set of state-level control variables (interactions of year with initial log light in 1992, growth of state-level light from 1992-2000, and shares of services and industry). T-statistics are shown in brackets. Standard errors are clustered at the state-level.

1.11 Figures

Figure 1.1: Distribution of Economic Activity in 2000

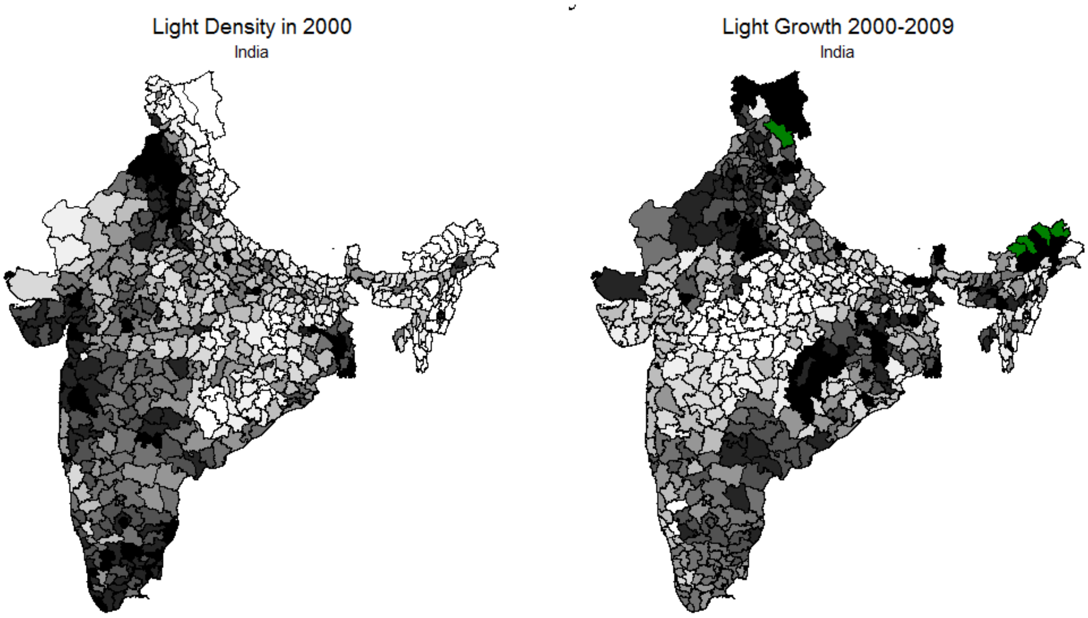
The figure shows the light intensity of each pixel in China and India in the year 2000.

Figure 1.2: Initial Density and Growth in China



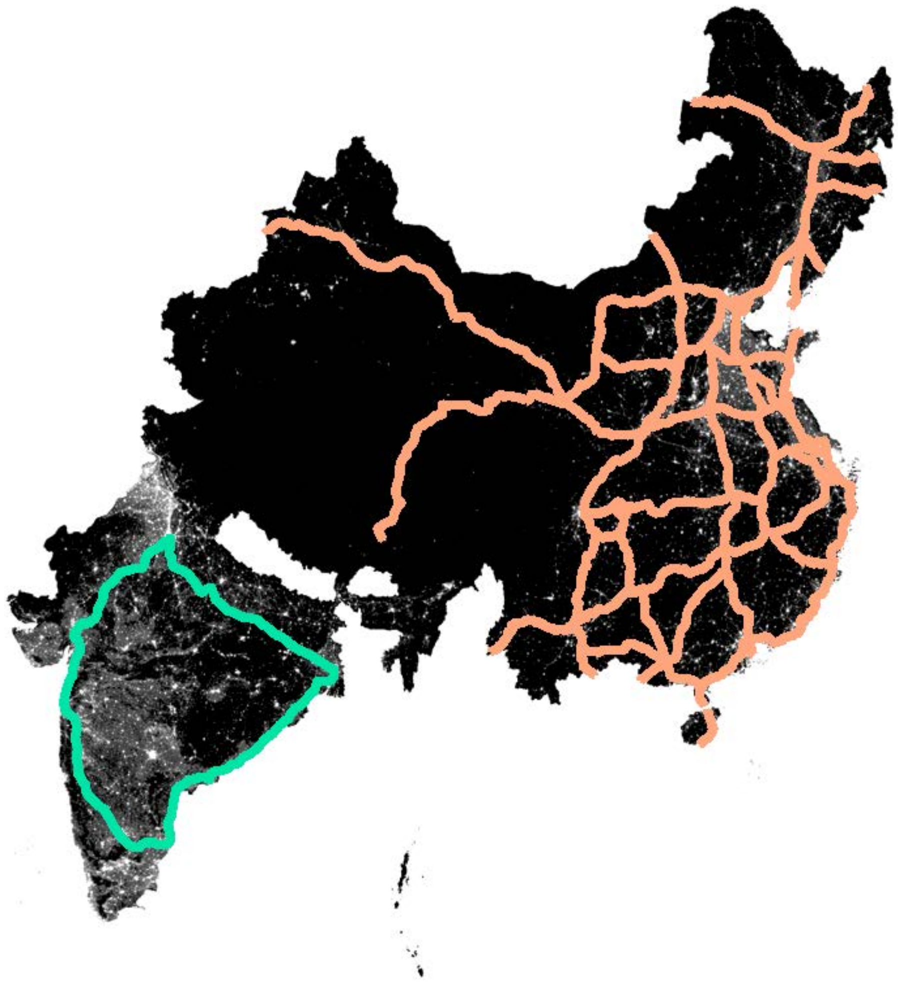
The two maps show the initial density (left map) and growth (right map) in light in China. The initial density measures the average light intensity per pixel in the year 2000. The growth rate measures the long difference in light intensity between 2000 and 2009. The units are 341 Chinese prefectures. Darker colors refer to higher density or higher growth rates.

Figure 1.3: Initial Density and Growth in India



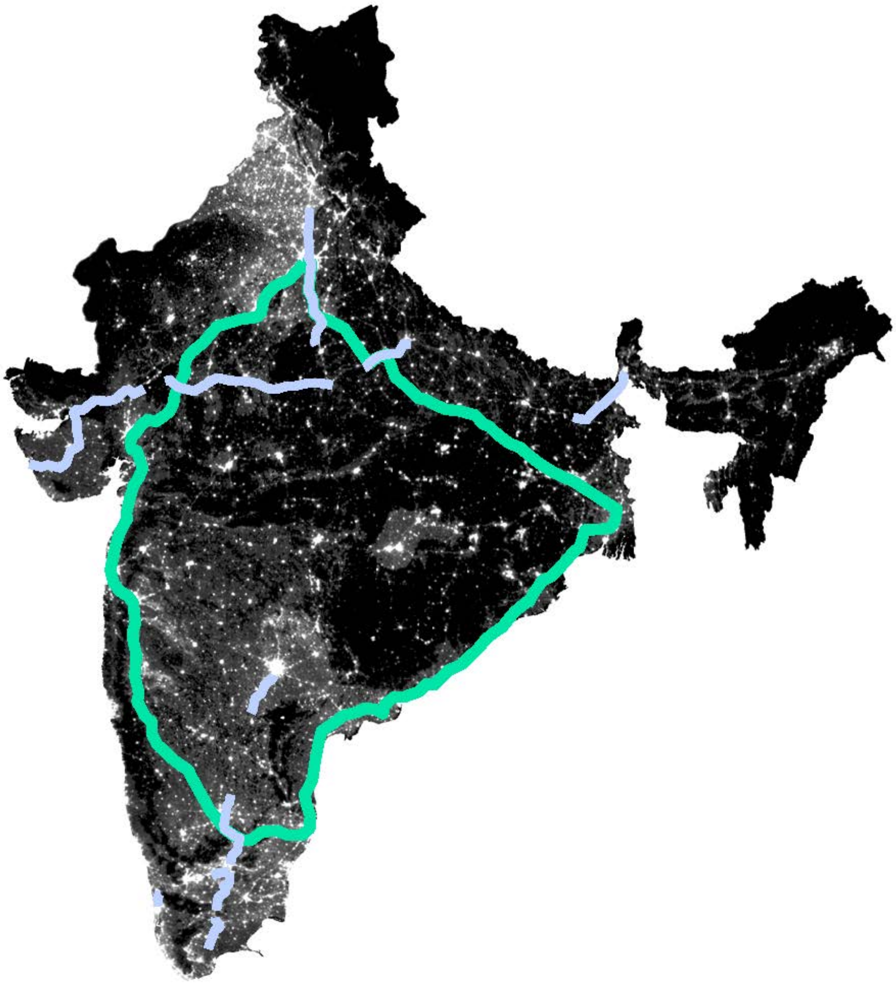
The two maps show the initial density (left map) and growth (right map) in light in India. The initial density measures the average light intensity per pixel in the year 2000. The growth rate measures the long difference in light intensity between 2000 and 2009. The units are 590 Indian districts. Darker colors refer to higher density or higher growth rates. The small green areas in the north and east represent missing observations due to zeros in the initial light per district.

Figure 1.4: Indian GQ and the Chinese NEN.



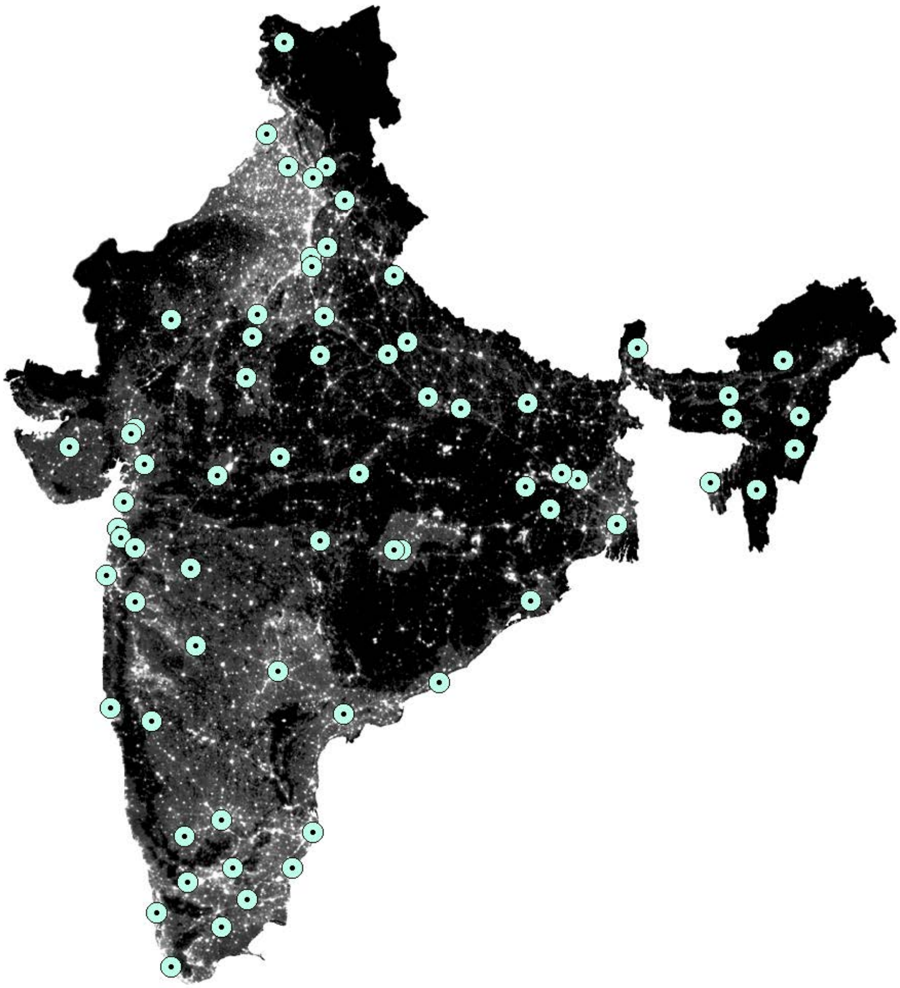
The figure shows the major highway investment programs in China (NEN, in red) and India (QG, in green).

Figure 1.5: Completed parts of the NHDP by 2010



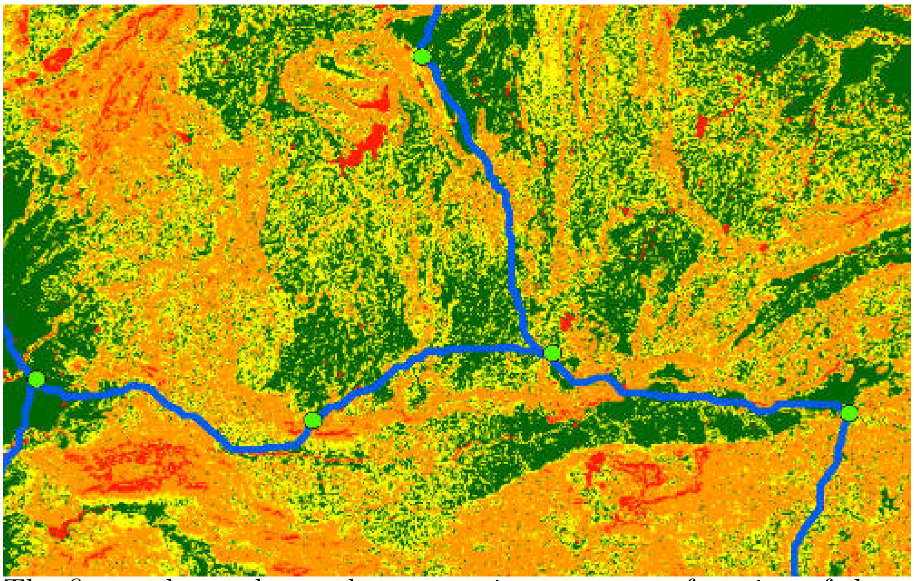
The map shows the parts of the NHDP which were completed by 2010. The GQ is shown as a thick green line and the finished NS-EW corridor parts are shown as thin blue lines.

Figure 1.6: Cities in India with more than 500,000 residents and all state capitals.



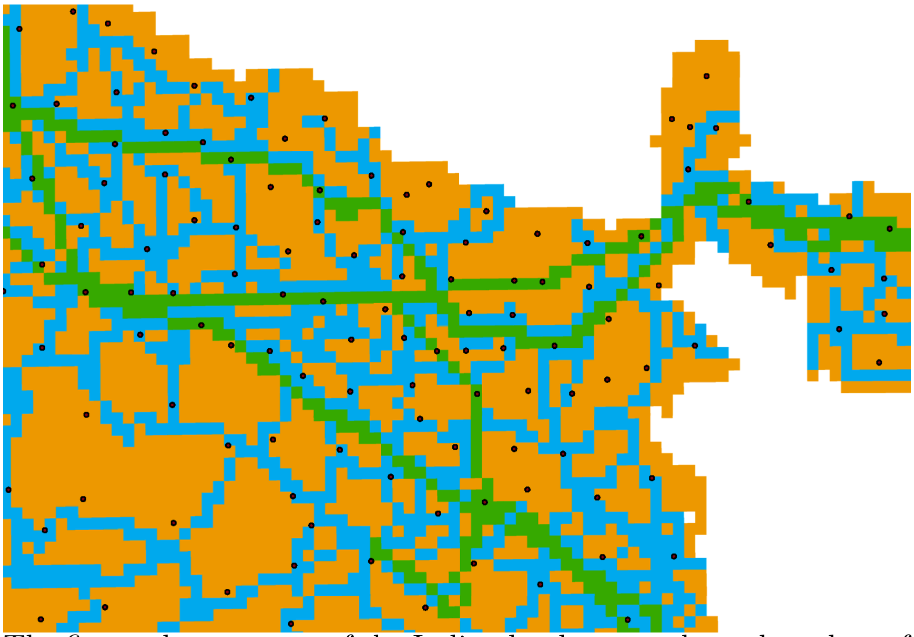
The figure shows the cities in India with more than 500,000 residents and all state capitals. The image in the background shows luminosity in the year 2009.

Figure 1.7: Road construction costs on the Indian terrain



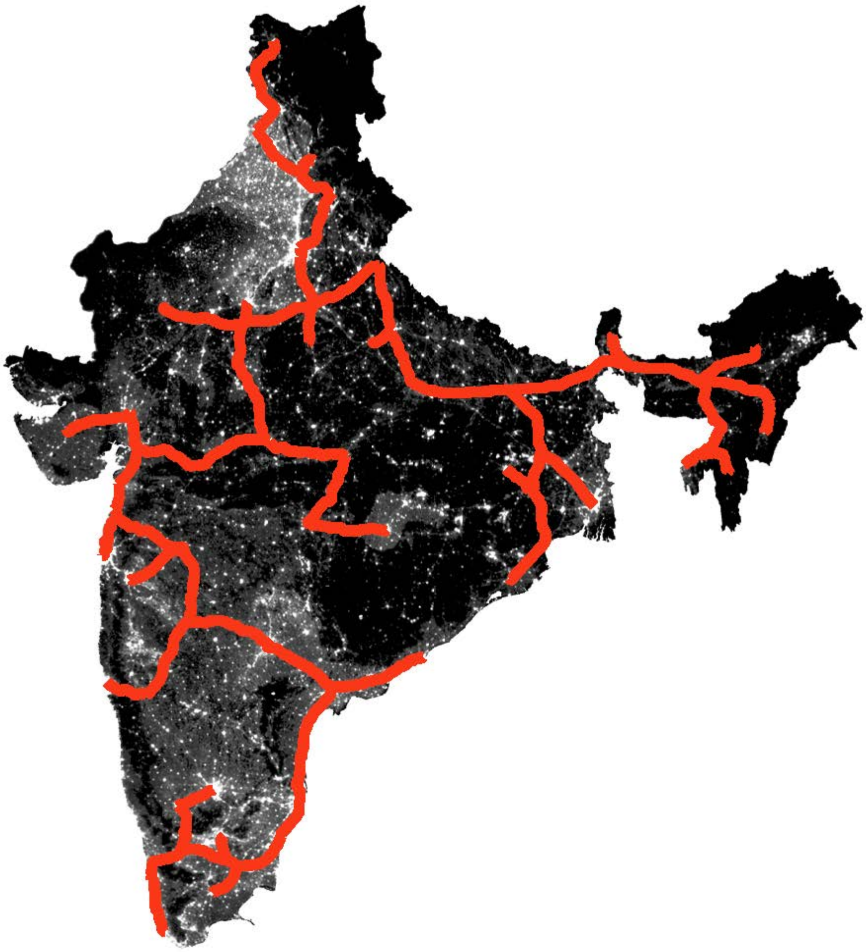
The figure shows the road construction costs as a function of slope and land cover. Dark red refers to high construction costs, orange and yellow to intermediate costs, and light green to low costs. The green circles represent cities in India which fulfill one of the two criteria of the Chinese NEN. The blue connections between the cities represent the cheapest construction routes.

Figure 1.8: Travel cost grid based on different qualities of roads



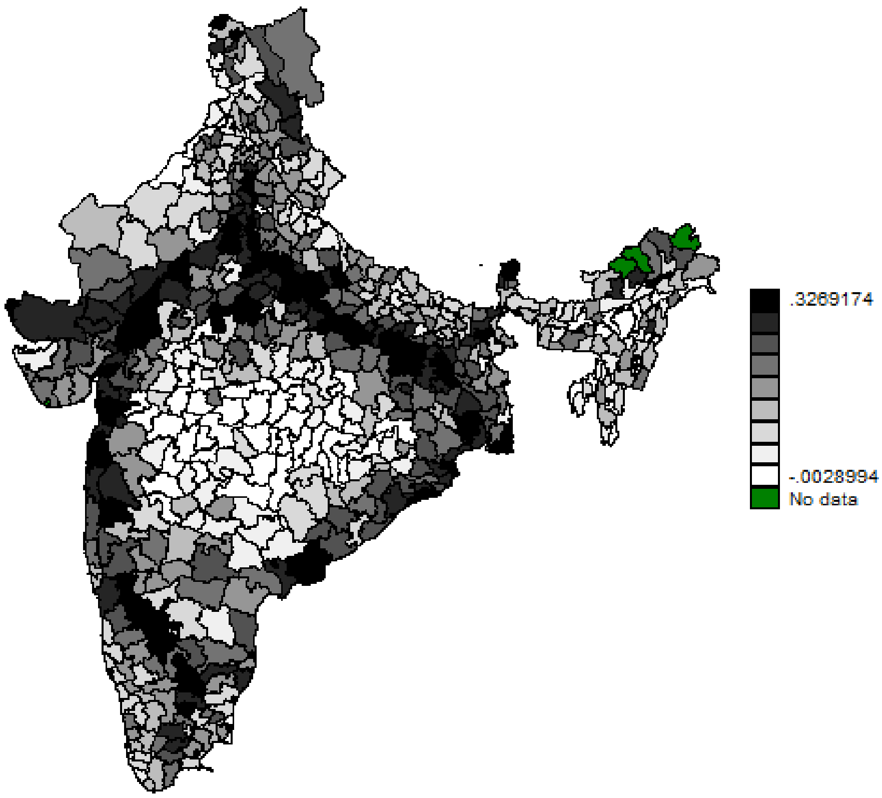
The figure shows a part of the Indian landscape, where the colors of different cells represent differences in travel costs. The green lines represent highways of the NHDP and the blue lines highways of lower quality. The dots represent the centroids of Indian districts between which bilateral trade costs are computed as the least-cost path through the cost grid.

Figure 1.9: Least-cost counterfactual network



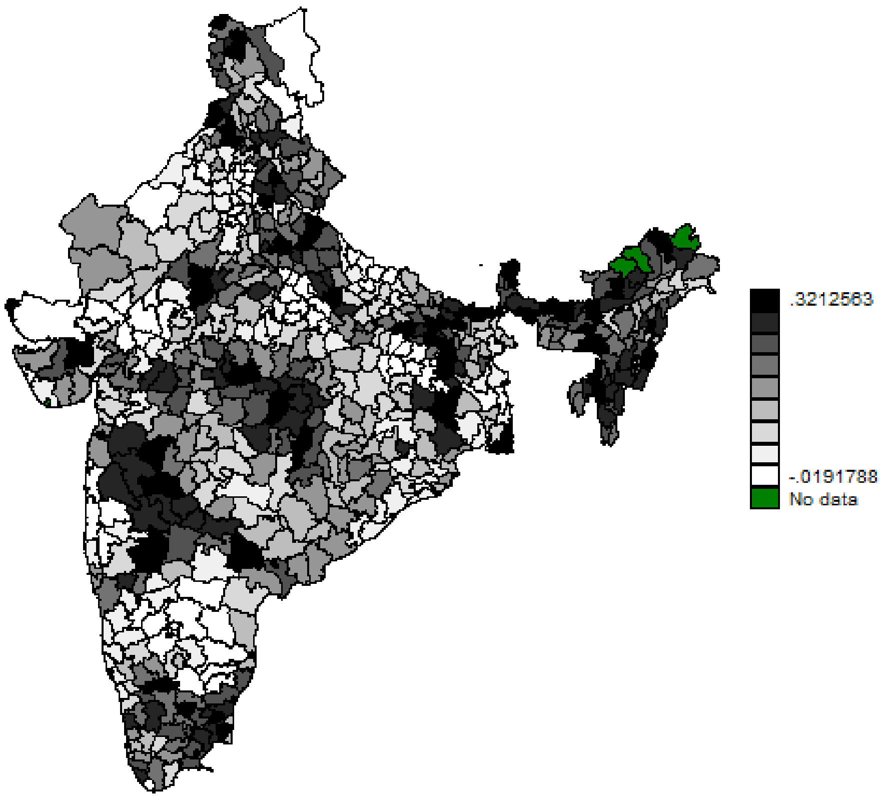
The map shows the counterfactual highways in India which connect all 68 targeted cities in a least-cost network.

Figure 1.10: Percent increase in income generated by the NHDP



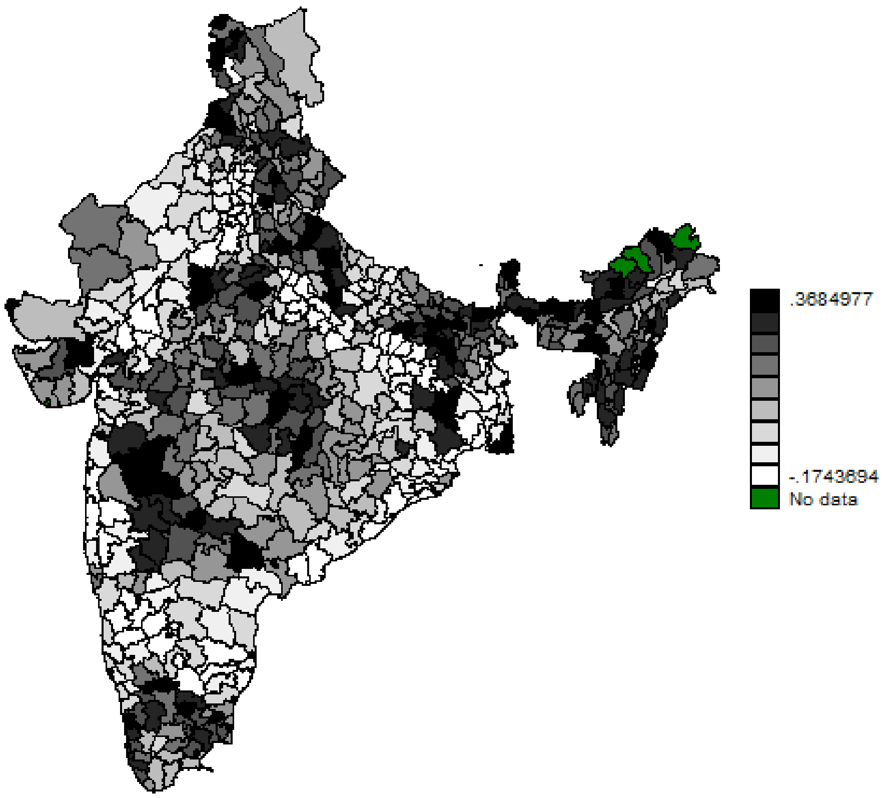
The map shows the boundaries of Indian districts. Darker color represents higher percentage difference in income generated by the NHDP until 2009 compared to a network without the NHDP.

Figure 1.11: Percent increase in income from adding counterfactual network



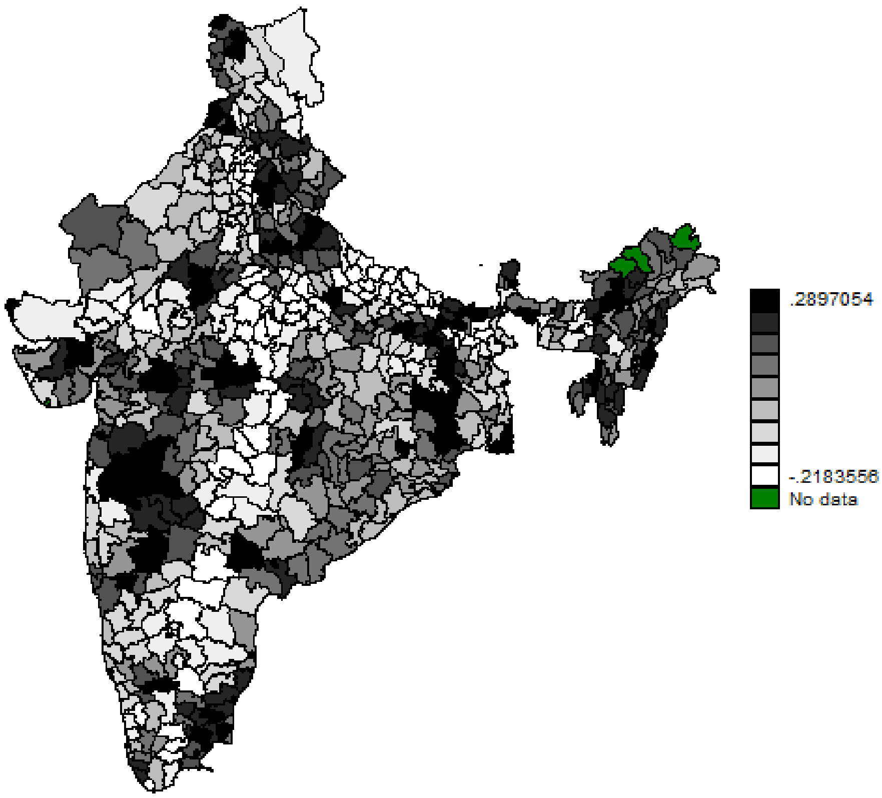
The map shows the boundaries of Indian districts. Darker color represents higher percentage difference in income generated by adding the counterfactual to the existing network.

Figure 1.12: Percent increase in income from replacing GQ with counterfactual



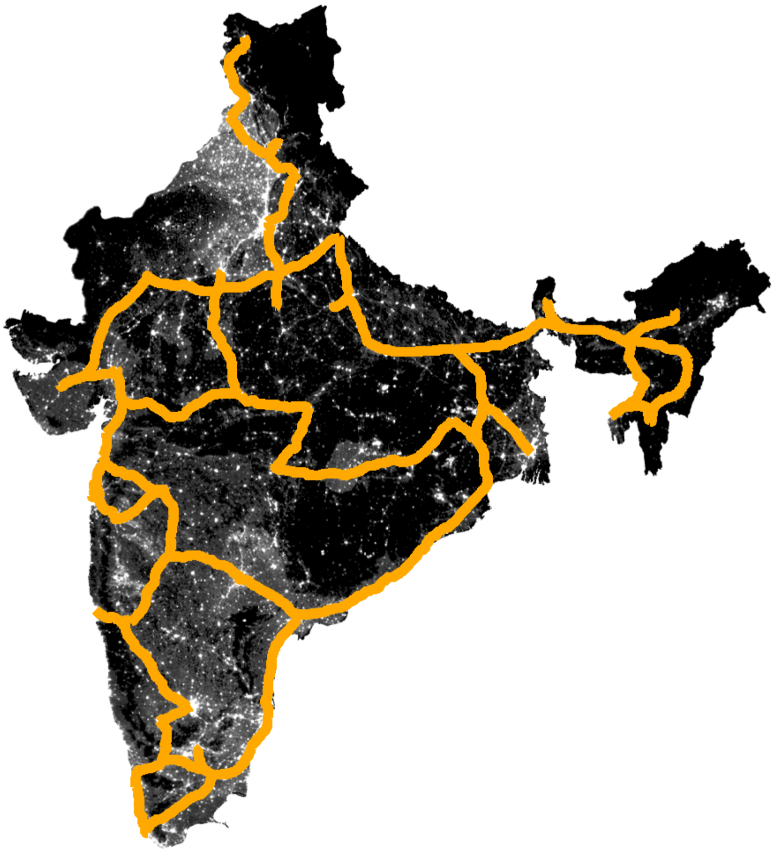
The map shows the boundaries of Indian districts. Darker color represents higher percentage difference in income generated by replacing the GQ with the counterfactual network.

Figure 1.13: Percent difference between counterfactual and completion of NS-EW corridors



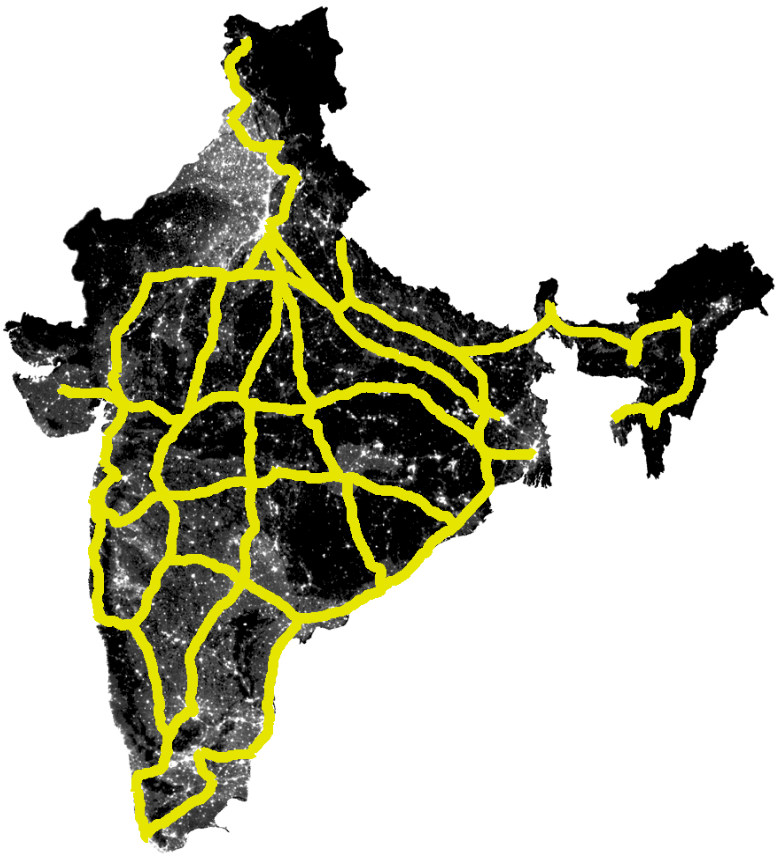
The map shows the boundaries of Indian districts. Darker color represents higher percentage difference in income between the counterfactual network and the completion of the planned NS-EW corridors.

Figure 1.14: Counterfactual network when connecting loose ends of the least-cost network



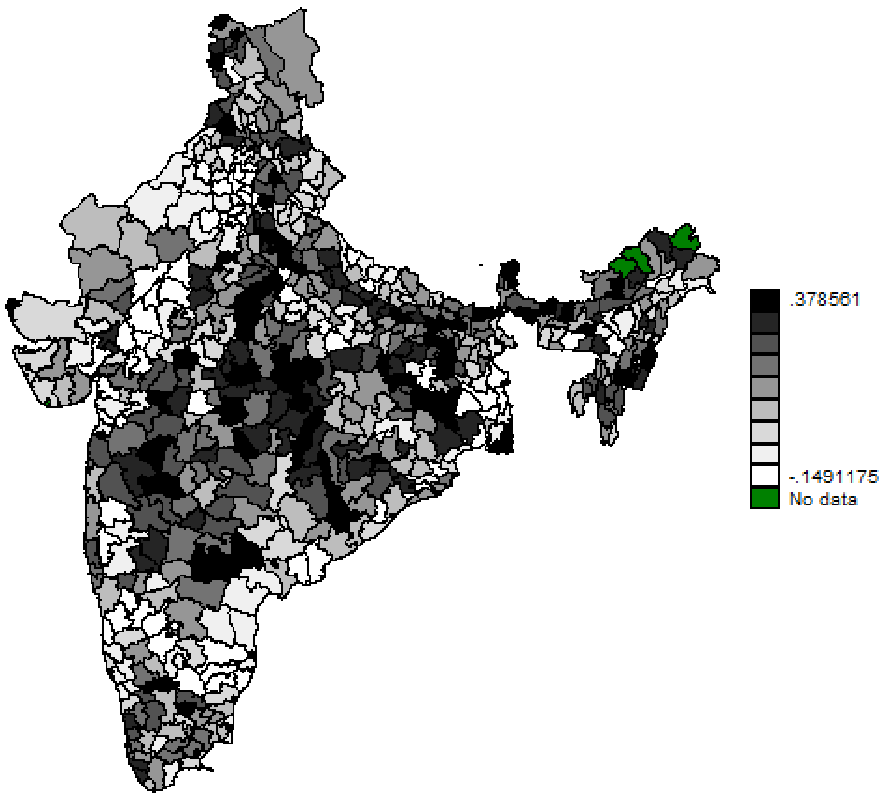
The map shows the counterfactual highways in India which connect all 68 targeted cities in a least-cost network and in addition connects loose ends.

Figure 1.15: Counterfactual network with rays and corridors



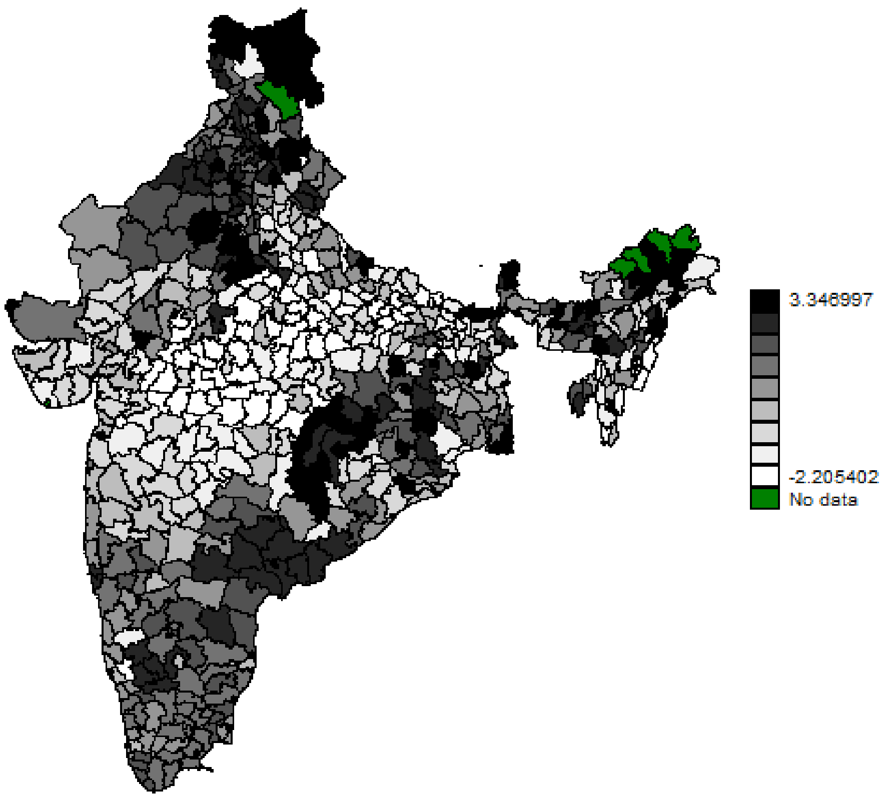
The map shows the counterfactual highways in India which connect all 68 targeted cities with rays, horizontal corridors, and vertical corridors following the Chinese strategy.

Figure 1.16: Percent increase in income from replacing GQ with counterfactual of rays and corridors



The map shows the boundaries of Indian districts. The colors represent percentage difference in income generated by replacing the GQ with the counterfactual network that is constructed by connecting cities with rays and corridors.

Figure 1.17: Growth of Light per Capita in India



The map show the growth of light per capita in India. Light is measured in the years 2000 and 2009. Population in each district is obtained from the Census in 2001 and 2011. The units are 590 Indian districts. Darker colors refer to higher growth rates. The small green areas in the north and east represent missing observations due to zeros in the initial light per district.

2 Economic Reforms and Industrial Policy in a Panel of Chinese Cities[1]

Joint with Lin Shao and Fabrizio Zilibotti

2.1 Introduction

The process of economic reforms launched in 1978, and gradually extended until current days, has catapulted China into a stellar growth trajectory that has proven highly resilient. These reforms affect a variety of policies and institutions. Even today, it is difficult to pinpoint which of its components were crucial. Yet, disentangling the sources of China's development boom is key to an accurate appraisal of its experience. China's transition has been fostered by economic institutions that differ significantly from those adopted by Western economies. For instance, market liberalization has gone hand-in-hand with a set of proactive industrial policies granting special status and privileges to specific cities, industries and regions. State intervention continues to play a major role in the economic activity today. While liberalization is a centerpiece of the orthodox doctrine, the imbalances and distortions to resource allocation imposed by China's industrial policy run against the tenets of the Washington consensus.

This paper aims at contributing to a better understanding of the policy roots of China's success by focusing on industrial policy. We exploit the variation across cities and years in the establishment of different types of Special Economic Zones (SEZ) to estimate the effects of SEZ on economic development. SEZ are a salient component of the reform process for a variety of reasons. First, they have been a centerpiece of the gradualist development strategy based on the learning-through-experimentation principle. Second, they have fostered an uneven development across geographic areas and sectors – possibly exacerbating inequality. Last but not least important, their effects are easier to measure than those of other reforms, as they took the form of well-defined changes in the legal status staggered across different Chinese regions and cities. The first SEZ were introduced as experiments in market allocation in geographically restricted areas along the coast. SEZ enjoyed special rules applying to labor markets, foreign direct investments, firms'

[1]This chapter is currently under revision at the Journal of Economic Growth.

ownership, and export controls. Another important difference from the rest of the country is that local political leaders were granted substantial autonomy and could shape key aspects of the industrial policy. After the success of the early experiments, SEZ were extended first to other cities along the coast and then, starting in the early 1990s, to inland regions. The establishment of new zones has continued until today. For instance, on September 29, 2013, the government of Li Keqiang has launched the Shanghai Pilot Free Trade Zone in the Pudong area, that will enjoy both full liberalization of foreign trade and capital market liberalization – the innovative aspect of this new zone. Although too recent to assess, the new experiment shows that the guiding principle of the SEZ continues to inform China's economic reform strategy.

We use a panel of 276 cities over the period 1988-2010 to compare development across treated and non-treated cities. Our econometric strategy is a difference-in-difference estimator controlling for time-invariant heterogeneity at the city level. We also control for province-specific shocks by using province×time fixed effects. We first regress (the logarithm of) GDP on a reform indicator that switches on (i.e., takes the unit value) in the year after a city has received SEZ status, controlling for city characteristics such as size and population. In our baseline specification, the introduction of a SEZ is associated with a permanent increase in the city's GDP level of about 12%. The result is robust to controlling for local government spending. To account for gradual effects of the reform, we also consider more flexible specifications where the effect of the reform is allowed to vary, both parametrically and non-parametrically, as a function of the time elapsed since the start of the treatment. We find an increasing cumulative effect of the policy treatment that flattens out after about ten years; the long-term effect of a SEZ is estimated to be a differential increase of about 20% in the GDP level.

Our analysis is subject to two important *caveats*. First, the assignment of cities to treatment and control groups may not be random. The Chinese government might have selected cities based on some prior knowledge that the conditions for industrial development might be especially favorable ("picking winners"), or to the opposite, in order to curb regional inequality. One might suspect the picking winners strategy to have been especially important in the first stage of the reforms, when all SEZ were chosen along the coast and close to potential trading partners and investors such as Hong Kong and Taiwan. Ideally, one would like to have valid instruments to isolate exogenous sources of variation in the reform treatment, but finding instruments is difficult in practice. We mitigate the concern with endogeneity through two complementary strategies. First, we restrict the sample to cities located in inland provinces where the selection of the zones was largely based on a rigid administrative criterion, i.e., being a provincial capital. Second, we augment the regressions with indicators for the immediate pre-reform years to capture differential trends. The results are reassuring in both cases: the effect of SEZ is robust in the restricted sample, and the pseudo-effects before the actual establishment of the zone are insignificant. Therefore, there appears to be a clear structural break around the reform year.

The second *caveat* concerns data quality. One might worry that local statistics be manipulated strategically by local officers in order to create the impression that an SEZ was successful so as to attract government support. In addition, while city-level nominal GDP data are available, city-level price deflators are more problematic (and only available for fewer cities/years). In our main specification, we use only nominal variables. The inclusion of city fixed effects removes any bias arising from time-invarying price level differences. Inflation differences across provinces are absorbed by the interaction between time and province fixed effects. Yet, this leaves open the possibility that different cities within the same province may experience different inflation rates. This would be a problem for our strategy if the SEZ status triggers systematically higher inflation rates, as in this case part of our estimated effect would be due to inflation. To address this concern, we first document that, in the more restricted sample for which we have data on prices at the city level, treated cities do not appear to have experienced higher inflation than did cities without SEZ. Next, we complement our analysis with alternative proxies of GDP that do not depend on prices: light intensity measured by satellites and electricity consumption. The results confirm the existence of robust significant effects of SEZ.

We also study the channels through which GDP increased as cities were granted SEZ status. First, we show that the treatment effect is positive and highly significant when one considers GDP per capita, instead of GDP levels, as the dependent variable. The estimated coefficient is almost identical between coastal and inland cities. Second, the treatment effect is strong and significant for capital labor ratios, showing that SEZ attract investments and trigger capital deepening. The effect on total factor productivity (TFP) and human capital also are positive, although with some *caveats*. For TFP the effect is positive and significant in the total sample, but insignificant (albeit positive) in the inland sample. The results for human capital are subject to data constraints, as census data are only available for three years. When we restrict the sample to census years, we find that the introduction of SEZ has a large and significant effect on the share of college graduates in the population.

Finally, one might suspect that the SEZ led to a concentration of resources in the SEZ, drawing resources away from adjacent areas. We find no evidence of such beggar-thy-neighbor effects. When we run our regressions at the prefectural level, a larger administrative unit that includes both the city core (our main unit of analysis) and a large surrounding periphery, and *exclude* the city core (where SEZ are hosted) we continue to find large positive effects. This suggests that there were no negative spillovers within prefectures, where if anything, crowding-in effects appear to prevail. However, our analysis cannot rule out negative externality across prefectures.

2.1.1 Related Literature

Our paper is related to a large literature on the effects of policy changes on economic development. We contribute to this literature by showing the effects of an important component of industrial policy in China. We are not first to study the effects of China's SEZ, although earlier studies, arguably due to data constraints, rely on comparisons of the cross-sectional variation in economic performance rather than on a difference-in-difference methodology. Wei (1993) uses city-level data for a sample of coastal cities where special policies were introduced in 1984, and documents that cities hosting SEZ have a significantly higher average growth rate during the early reform period, while other types of preferential policies do not produce the same effects.[2] Since his sample ends in 1990, when only a small subset of the cities had been granted the status of SEZ, his identification relies on the cross-sectional comparison between early reformers – a small and arguably selected group – and cities that were never granted the SEZ status at the time of his study. Wei's pioneer study is extended by Démurger *et al.* (2002) and Jones *et al.* (2003), who also document differences in growth rates between treated and non-treated cities. Different from these articles, our study exploits the staggered establishment of SEZ across cities. This allows us to estimate the treatment effect controlling for time-invarying heterogeneity (city fixed effects) and time-varying province-level shocks.

Other studies focus on different economic outcomes. Cheng and Kwan (2000) show that provinces hosting SEZ attract significantly more foreign direct investment (FDI) than do other provinces. A recent study by Wang (2013) uses a panel of Chinese cities and finds, using a difference-in-difference approach similar to ours, a strong positive effects of SEZ on FDI, exports, and the output of foreign enterprises. The effects on other outcome variables (which do not comprise GDP) are smaller and less robust. Our findings are complementary to Wang (2013) insofar as we focus on GDP, a comprehensive measure for the development of the local economy, while her study focuses on direct intermediate targets of the policy. An important difference for our analysis is that we distinguish between state-level and province-level SEZ (see below for a detailed motivation for this choice). Without drawing such a distinction, the introduction of SEZ yields no statistically significant effect in our sample. Some studies document the effect of China's SEZ at the firm level. Head and Ries (1996) analyze the location decision of international firms in Chinese cities and

[2]Wei (1993) uses two samples: the first has 434 cities but only a limited time variation from 1988-1990. The second sample includes fewer cities (74) and covers the period 1980-1990.

find that SEZ have a positive effect that this is amplified by agglomeration economies. Schminke and Van Biesebroeck (2013) estimate the effect of being located inside SEZ on firm's productivity and export behavior. They find that firms in SEZ export more, have higher output per worker and higher capital intensity, but no higher TFP once selection is controlled for.

Zones with special policies are not unique to China (see Akinci and Crittle 2008). In a recent study on US "Empowerment Zones", Busso *et al.* (2013) compare locations selected for special treatment, such as tax-credits and subsidies for disadvantaged neighborhoods, with similar locations that were rejected or treated in a second round. They conclude that the policy had significantly positive effects on employment and wages, while the efficiency costs were relatively small.

Our study also relates more generally to a large literature on liberalization and industrial policy, including specific applications to the Chinese reform process.[3] Rodrik (2006) argues that government policies creating distortions in favor of more advanced industries had an important role in the success of Chinese reforms. Dewatripoint and Roland (1995) and Rodrik (2004) argue that, through experimentation, the state can generate information about the potential of different sectors. Our findings are broadly consistent with these theses. Finally, our study has some similarity in both the methodology and motivation with Aghion *et al.* (2008) studying the effect of industrial policy (the demise of the License Raj) in India. Similar to our study, they exploit the fact that the reforms were staggered across time and sectors. However, different from our study, they emphasize the interaction between the reform and state-level characteristics of the labor market. Moreover, they study an episode of pure liberalization (delicensing) while China's industrial policy also entails proactive policy elements (tax credits, subsidies, etc.).

The rest of the paper is structured as follows. Section 2.2 provides an overview of the institutional background of economic reforms in China with special focus on SEZ. Section 2.3 describes the data sources and the sample. Section 2.4 discusses the empirical strategy and the main results. Section 2.5 performs a variety of robustness checks. Section 2.6 concludes.

2.2 China's Economic Reforms and Institutions

Since its establishment in 1949, the People's Republic of China relied on rigid economic planning. The State Planning Commission, a division of the State Council, was in charge of economic development. The two decades preceding Mao's death in 1976 were characterized by low and volatile economic growth, and by an intense social turmoil. The reformist

[3]See Perkins (1988), Naughton (2007), Brandt and Rawski (2008), and Xu (2011).

political leadership that won the battle for Mao's succession in 1978, led by Deng Xiaoping, faced the desperate need for measures to reconstruct social cohesion and revitalize the economy. There were, however, no existing blueprints showing how to proceed. Learning-through-experiment became then the guiding principle of economic reforms. As Deng put it: "one has to grope for stepping-stones as he crossed the river".

The first policy breakthrough happened in rural areas, where agricultural production until then had been carried out in collective communes. Under a new production system which was later called the Household Responsibility System, farmers were entitled, after fulfilling their procurement quota, to the rest of their agricultural output. The new system was first implemented in Anhui and Sichuan provinces and extended to the whole country by the end of 1982. It was a major success. The national grain harvest increased from 304.8 million tons in 1978 to 407.3 million tons in 1984.

The leadership soon realized that reforms had to be extended to the urban area, and that industrialization necessitated opening up China to foreign investments. However, the reformists' plans to open the economy met the strong resistance of the conservative fraction of the Communist Party (CCP) central committee. To the conservative ideologists, renting China's land to foreign companies and allowing them to exploit China's cheap labor would mean selling out China and exposing it to the influence of western ideologies.

1980-1984

The establishment of SEZ resulted from the compromise between the reformist and conservative forces. In the year 1980, four cities in the provinces of Fujian and Guangdong, Shenzhen, Zhuhai, Shantou and Xiamen, were granted the status of SEZ. These are geographically limited pieces of land and usually located in the suburban areas of cities. The SEZ were given special economic treatment, including tax deduction and special tariffs for import and export as well as less regulation on foreign exchange and land use. Foreign firms that resided inside of the SEZ enjoyed first two years of tax holiday, then three years of a low tax rate of 7.5%, and after the initial five years a tax rate of 15% (outside of the zones, the tax rate for foreign firms was 33% and for state-owned firms 55%) (see Wei 1993).

The location of the zones was carefully chosen. First, all were located in cities on the southeastern coast of China, far away from the political center Beijing. There, local officials, facing less political resistance from the conservative leaders in the central committee, had more freedom and flexibility to design and implement innovative policies. Second, the zones were geographically close to Hong Kong, Macau and Taiwan. Over the past several hundreds of years, the people in Guangdong and Fujian province had established deep connections with the overseas Chinese through kinship and trade.

The idea of SEZ was *per se* no Chinese innovation. China's SEZ inherited some essential characteristics of the Export Processing Zones, which had already been established in over 80 countries by 1980 (Naughton 2007, and Vogel 2011). Like the Export Processing Zones, the SEZ were designed to circumvent the complex rules of import and export. China's SEZ were special in the sense that they also bore the responsibility of policy innovation and experimentation. They were the laboratories for the market economy. According to the official document issued by the party center and State Council, "the four Special Economic Zones would carry on systems and policies that are different from other places. The Special Economic Zones will be regulated primarily by the market." (Vogel 2011: p.399). The local officials of the zones were implicitly encouraged to be innovative in designing economic policies and institutions. Many of the policy innovations inside of a zone, including the establishment of China's first labor market in Shenzhen, were deemed illegal outside of it. They were, however, later extended to the rest of the country after proving successful.

1984-1991

The success of the SEZ was remarkable: between 1980 and 1984 Shenzhen grew at an annual rate of 54%, and in 1984, the four SEZ alone attracted 26% of China's total FDI. In addition, the zones had developed a set of well-functioning markets for labor, land, capital, transportation and technology (Zeng 2010). The success of the four SEZ strengthened the reformist fraction in the CCP and softened the position of the conservative leaders. In 1984, 14 coastal cities were granted the right to build Economic and Technological Development Zones (ETDZ). The ETDZ shared most of the policies and privileges granted earlier to the initial four SEZ. Many of the 14 cities were old treaty ports that were opened up at the end of the Qing Dynasty. Even before receiving the special status, these cities, with an established industrial base and a well educated labor force, were among the most developed areas in China. According to the official statistics, the 14 coastal cities constituted 21.8% of the national total industrial output in 1985.

1991-2003

During January and February of 1992, Deng made his celebrated tour to southern China, including stops at the SEZ of Shenzhen and Zhuhai, to mark the end of a period of political instability and to restate the commitment of the CCP to the reform process. Shortly afterwards, a new SEZ called Pudong New Area, was established in Shanghai. In May, the CCP's party center issued document No. 4, announcing the plan to grant the five inland cities along the Yangtze River, nine border cities and all thirty of the provincial capital the same privileges as the SEZ (Fewsmith 2001). Following the instruction, 18 state-level

ETDZ were approved during 1992-1993 and 17 more during 2000-2002, all located in inland provinces. Another type of zone, the High-tech Industry Development Zone (HIDZ), was also established during the same period. The establishment of the HIDZ was an essential part of the "Torch Program", a program carried out by the Ministry of Science and Technology to guide and facilitate the development of China's high-tech industries. ETDZ and HIDZ were granted the same preferential policies and administration status. However, they emphasized different goals of the development strategy. The main goal of HIDZ was to help transform domestic research outcomes into profitable high-tech companies. The HIDZ were located in cities with many universities and research institutions. In several cases, the HIDZ and ETDZ were located in the same city, with HIDZ established several years ahead of ETDZ.

2003-present

During the past ten years, the reform of SEZ spread quickly across China. By the year 2005, the system of state-level development zones comprised 54 ETDZ, 53 HIDZ, 15 Bonded Zones (BZ) and 60 Export Processing Zones (EPZ).[4] In the year 2005, the 54 ETDZ contributed 4.49% of the national GDP and 14.93% of national export (Ministry of Commerce 2006). Establishing a development zone became a common strategy for the local government to attract FDI and foster local economic growth. Through shuffling local officials across different regions, the governments diffused the knowledge and experiences accumulated in the early zones to help develop new SEZ (Xu 2011). Figure 2.2 shows that by 2010 SEZ had been established throughout the country.

Besides the state-level zones, a large number of lower-level zones also were established during the same period. On the one hand, the preferential policies, given by the central government to the state-level zones, did not apply to these lower-level zones. On the other hand, the lower-level zones were not under close monitoring and regulation of the central government. In December 2003, the State Development and Reform Commission, the Ministry of Land and Resources, the Ministry of Construction, and the Ministry of Commerce together issued Document No. 2343 to request a thorough investigation into development zones regarding the violation of the land-use plan. Before the investigation, there were a total number of 6866 development zones of all levels (WEFore 2010). By the end of 2006 when the investigation came to an end, only 1568 zones survived and gained official approval from the state (see State Development and Reform Commission (2006) for the list of zones). A large number of the development zones were abolished following the investigation, including all zones at a lower than province-level and several

[4]BZ were mainly free trade zones. Most of the EPZ were established within existing SEZ. They were regulated by local customs to assist firms' import and export.

province-level zones. After 2006, there existed only two levels of development zones – state-level and province-level. Starting from 2010, a number of province-level zones were promoted to state-level conditional on passing certain standards, including performance in economic growth, production safety and environmental protection. By the end of 2010, the number of state-level ETDZ had increased from 54 to 88.

2.2.1 Experimentation and Convergence in the Policies of the Zones

During the early stage of the development of SEZ, the policies were intended not only to attract FDI but also to foster institutional innovation. Therefore, except for tax deduction, protection of private property and land-use policies, local governments were given significant freedom to design new institutions. Successful innovations were retained and extended to later waves of development zones (see Yeung *et al.* (2009)). Gradually, the institutional structure of the SEZ became stable. Policy treatment became uniform across all state-level ETDZs and HIDZs. At present, the preferential policy treatment for the state-level ETDZ and HIDZ includes: 1) tax and customs duty deduction, 2) discounted land-use price, 3) no regulation on labor contracts and 4) special treatment on bank loans.

2.2.2 Different Types of the State-level Development Zones

There are five types of state-level development zones: comprehensive SEZ (a label we use to distinguish the early created special zones from the broad notion of SEZ), Economic and Technological Development Zone (ETDZ), High-tech and Industrial Development Zone (HIDZ), Bonded Zones (BZ), Export Processing Zone (EPZ) and Border Economic Cooperation Zones (BECZ). They all share the same preferential treatment in terms of tax deduction, custom duty deduction, reduced land-use price, flexibility in signing labor contract and financing. But the types of zones differ along several dimensions. First, they are administered by different authorities. Among them, the comprehensive SEZ, ETDZ and HIDZ are directed by State Council (HIDZ is co-directed by the Ministry of Science and Technology). BZ and EPZ are directed by customs. BECZ were directed by the State Council until 2007, and are now under the control of the Ministry of Commerce.

Second, the zones reflect different aspects of the development plan. The comprehensive SEZ, located in Shenzhen, Zhuhai, Xiamen, Shantou, Hainan, Shanghai and Tianjin, are the largest in scale and enjoy the most autonomy among the zones. They are expected to play an active role in defining the frontier of economic and social development. The ETDZ share similar policies and development goals with the comprehensive SEZ, such as attracting FDI and boosting export, only on a smaller scale. Although the institutional innovation was more active and frequent at the early stage of the reform process, even today the comprehensive SEZ and ETDZ are encouraged to design and experiment with new institutions and policies. The HIDZ, which are co-directed by the Ministry of Science and Technology, focus on fostering the domestic high-tech industries. The BZ are typical free trade zones: small and closed areas where import and export can take place at a faster speed. They are all located in coastal port cities or border cities, which also helps to develop the logistics industry. The function of EPZ is "export processing", which means to import raw materials from abroad, process them and export the final goods without entering the real territory of China. Many of the EPZ are established inside of the ETDZ and HIDZ. The BECZ intend to take advantage of the location of the border cities to foster trade with other countries.

2.2.3 The State-level and Province-Level Zones

State-level and province-level development zones co-existed during the 30-year history of the economic reform. In some cities, province-level development zones were established before the state-level zones. Despite some commonalities, there are fundamental differences between state-level and province-level SEZ suggesting that their effects might be highly diverse. First, province-level zones include areas where the special status meant *de facto* almost nothing. This causes a rampant measurement error problem that is much less severe for state-level zones.

Second, the preferential economic policies granted to the province-level zones have been heavily constrained by the administrative and legislative power of the provincial government. The state council explicitly requested that "the policies given to the province-level development zones should not be comparable to those given to the state-level ones", in order to prevent excessive competition between the zones and the waste of land resources (State Administration of Taxation 2004). In reality, the policy treatment of the state-level zones normally included both the policies usually accorded to provincial zones and farther-reaching measures granted under the direct control of the central government.

Another difference is that in many cases province-level zones targeted specific industries (often catering to local interest groups). In contrast, the most important policies of the state-level zones, such as tax and custom duty deduction, were generally industry-blind. If there are exceptions to this principle, they reflect a general strategy of the government (such as the promotion of the development of particular industries nationwide) rather than the influence of local interests: for instance, in recent years state-level zones have favored high-tech industries.

In Table 2.1, we list the number of state-level and province-level development zones and their average share of industrial output in three coastal provinces hosting a large share of SEZ. The data are from WEFore (2010) for the year 2009. All three provinces have a larger number of province-level than of state-level zones. However, the state-level zones account for a far larger share to industrial output. We will show that, empirically, state- and province-level zones have very different effects on economic development at the city level.

2.3 Data

In this section, we describe the variables we use in the empirical analysis. Our data come from two main sources. First, the official statistics from the National Statistics Bureau of China (NSB) including GDP, electricity consumption, population, education, government spending, and land area. We also use the light intensity data from weather satellites as a proxy for GDP. More detailed information about our data sources is provided in the appendix.

The main unit of analysis is the core urban area of a *prefecture-level city,* an administrative division ranking below a province and above a county in China's administrative structure. A prefecture-level city comprises a core urban area (corresponding to the standard notion of city area) and a large surrounding area that may include rural areas, other smaller cities, towns and villages. Since SEZ are located in core urban areas, and the NSB reports separate statistics for the core and periphery of each prefecture-level city, we focus on the urban core of prefecture-level cities, unless we state otherwise. A more detailed discussion and motivation of this choice of the unit of analysis is deferred to the appendix. For simplicity, henceforth, we refer to the the core urban area of a prefecture-level city as a *city* and to the whole prefecture-level city area as a *prefecture.*[5]

2.3.1 Main Variables

We denote by i the city, by p the province, and by t the year.

2.3.1.1 Dependent Variables

- $\log GDP_{ipt}$ is the logarithm of nominal GDP at the city level from the *China City Statistical Yearbooks.*

- $\log \frac{GDP_{ipt}}{L_{ipt}}$ is the logarithm of nominal GDP per capita at the city level. The population L_{ipt} is taken from the *China City Statistical Yearbooks.*

[5]In the *China City Statistical Yearbooks*, the *prefecture* is called "di ji shi" and the *city* is called "shi qu".

- $\log Electricity_{ipt}$ is the electricity consumption at the city level from the *China City Statistical Yearbooks* (available for the same set of cities as GDP). It measures the use of electricity for household consumption and industrial production and is a proxy for the level of economic activity.

- $\log Light_{ipt}$ is the average light intensity at the city level, another proxy for economic activity. In the data provided by the National Geographical Data Center, light intensity is measured on each square km (pixel) on a discrete scale from 0-63. We use digital maps of Chinese cities to aggregate the light intensity of the pixels to administrative units.

- $\log \frac{K_{ipt}}{L_{ipt}}$ is the logarithm of physical capital per capita. The physical capital stock K_{ipt} is constructed with the perpetual inventory method. To construct the physical capital stock, we take the data on new investment for the period 1988-2010 from the *China City Statistical Yearbooks,* and assume an annual depreciation rate of 8%. For some cities, we collect the new investment data from *New China in 60 Year Provincial Statistical Collection* for the earlier period 1978-1987. The province-specific series of investment deflator is obtained from *New China in 60 Years Statistical Collection.* The population L_{ipt} is taken from the *China City Statistical Yearbooks.*

- $\log h_{ipt}$ is the logarithm of average human capital, constructed using average educational attainment of population over the age of 6. The educational attainment data comes from *China Population Census.*

- $\log A_{ipt}$ is the logarithm of TFP, constructed as a standard Solow residual.

2.3.1.2 Explanatory Variables

Our main explanatory variables are indicators for the presence of a SEZ. More precisely, for each of the different types of SEZ we construct a dummy, I_Reform_{it}, which switches on (i.e., takes the unit value) in the year *after* the establishment of a zone and retains the unit value in all following years. Formally, we define the reform indicator based on the establishment of a zone as

$$I\_Reform_{it} = \begin{cases} 1 & \text{if } ReformYear_i < t \\ 0 & \text{otherwise.} \end{cases},$$

where $ReformYear_i$ is the year in which a zone was established in city i and t is the current year. Note that for cities that never host a zone $I\_Reform_{it} = 0$ for all t. We also construct separate dummies for each lag from the reform year, as discussed in more detail in the empirical sections.

2.3.1.3 Primary Control Variables

We use two main control variables from the *China City Statistical Yearbooks*. First, the geographic size of the city, to which we refer as land area measured in square kilometers. This variable is available at both the city and prefecture level, and varies over time reflecting changes in the legal city boundaries during the reform period. The second control variable is population, which again we observe for each city and prefecture. Although population is partly endogenous to the establishment of a SEZ, we find it useful to filter out the part of the SEZ's effect on GDP that originates from mere population changes. In Section 2.5 we add to the list of control variables the expenditure of the local government, also from the *China City Statistical Yearbooks*.

2.3.1.4 Fixed Effects

We include in all regressions two sets of dummies in order to control for unobserved heterogeneity. Time-invariant city characteristics are absorbed by city fixed effects. Time-varying heterogeneity at the province-level is absorbed by province×time fixed effects. In some regressions we also include city-specific linear time trends.

2.3.2 Price Data

The *China City Statistical Yearbooks* published by the National Bureau of Statistics report nominal GDP for the period 1988-2010. We rely on this source because it provides a consistent measurement of GDP across cities and years. Since Chinese price data are regarded as somewhat unreliable (see, for example, Young 2003), we opt to use nominal data. Time invariant differences in price level across cities and time varying inflation differences across provinces are absorbed, respectively, by city and province×time fixed effects. This approach would be problematic if inflation rates differed significantly across cities within each province. The main concern is that the SEZ treatment might increase systematically local inflation. We check if there are differences in inflation rates between treated and non-treated cities in those years for which real GDP data are available from the NBS. More precisely, we compute an implicit city-level deflator using the data on nominal and real GDP, and compare it between cities with and without a SEZ. We find that, within each province, cities with a SEZ did not have higher inflation.[6] As an alternative strategy

[6]A real GDP index of prefecture level city centers is available from the NBS for the period 2002-2010. For this period, cities with a SEZ had an average yearly inflation rate (as implied by the implicit deflator

that avoids relying on prices altogether, we use electricity consumption (in GWh) and light intensity as proxies for the level of economic activity.

2.3.3 Sample

The sample period is 1988-2010 for the *China City Statistical Yearbooks* and 1992-2010 for the light data. For this period, we have a consistent definition of city borders, and information on the main variables of interest.[7] We focus on 276 cities, excluding from our analysis the four cities in which comprehensive SEZ were introduced before 1988, as well as Hainan, where the entire province received the status of SEZ in 1988. Furthermore, we exclude Tibet, where we have data for only one city, and the province-level municipalities, including Beijing, Chongqing, Shanghai and Tianjin, because our set of province-time fixed effect would absorb all variation in GDP.

2.4 Empirical Strategy and Results

In this section, we discuss the econometric strategy and the main results. We use a difference-in-difference estimator exploiting the variation in economic policy across cities and years following the establishment of SEZ. The main dependent variable is GDP at the city level, which we measure in three alternative ways: first, from official statistics (this section), then using light intensity and electricity consumption as proxies of the level of economic activity (section 2.5).

Table 2.2 shows the summary statistics of our dependent variables and of the main control variables. We have over 5100 observations for GDP from an unbalanced panel of 276 cities from 1988 to 2010. Our policy variable, the establishment of SEZ, is illustrated in Figure 2.1. This figure shows the time evolution of the shares of cities hosting the different types of zones in the balanced sample. The two most important types of zones are HIDZ and ETDZ with shares reaching 31% and 24% in 2010, respectively. Two types of zones existed before the start of our sample: the comprehensive SEZ, established in 1980, and a few early ETDZ, established in 1984. ETDZ and HIDZ are altogether the most frequent zone types. We also consider Export Processing Zones (EPZ) and other

constructed from nominal and real GDP series) of 3.3%. Cities without a SEZ had an average yearly inflation rate of 4.0%. This suggests that reformer cities, if anything, have a lower inflation rate, although the difference is not statistically significant. The data on real GDP of the prefecture (instead of the city) dates back until 1996. When using this longer time series, we find that prefectures with a SEZ had an average yearly inflation rate of 1.8%, while prefectures without a SEZ had an average of 2.3%. The difference is again not statistically significant.

[7]During the period of economic reforms, there was also a reform of the administrative levels and borders of cities. Our data from the National Bureau of Statistics provide a consistent definition across cities and time.

less frequent types of zones (e.g., BZ and BECZ), introduced in cities that already hosted either ETDZ or HIDZ. We control for province-level zones, but we do not combine these with our state-level SEZ because these are more limited in scope and highly heterogeneous, as discussed above.

2.4.1 Baseline Specification

Our baseline specification is a city-level panel regression whose dependent variable is the log of GDP. The main explanatory variables are reform indicators switching on in the year after part of a city's territory is granted the status of SEZ.[8] Note that cities may have multiple zones of different types. Since our goal is to assess the effect of different types of zones, in some specifications we allow each city to be subject to multiple treatments. All regressions control for city fixed effects and province-time interaction dummies. Standard errors are clustered at the city-level. More formally, we run regressions of the form

$$y_{ipt} = \phi_i + \gamma_{pt} + \alpha\, I\_Reform_{it} + X_{it}\beta + \varepsilon_{it}, \tag{2.1}$$

where y_{ipt} is log nominal GDP, ϕ_i is a city fixed effect, γ_{tp} is a province-time fixed effect and I_Reform_{it} is an indicator switching on, for each city, in the year after a SEZ is established. X_{it} is a vector of time-varying controls including log land area and log population. ε_{it} is a normal error term. City fixed effects absorb time-invariant heterogeneity in city characteristics like initial development or geographical location. Thus, the effects of reforms are identified across city-time within each province. Province-time fixed effects control for time varying province-specific shocks that can play a confounding role. In particular, they absorb cross-province inflation differentials.

The econometric specification in (2.1) restricts the treatment effect to a shift in the after-reform GDP level path, namely, in reformed cities the GDP *level* (or trend) is allowed to shift whenever the reform indicator switches on. This specification is clearly restrictive. One might expect reforms to have cumulative effects on development, such as temporary or even permanent changes in growth rates. For this reason, we explore below more flexible econometric specifications allowing for trend breaks and distributed lags.

We start our analysis by aggregating all state-level reforms into a single indicator switching on after a city is granted, for the first time, the status of any state-level SEZ. We construct a similar single dummy for province-level reforms. The estimated coefficients are shown in Table 2.3. In column (1), we include no additional control variable except for the fixed effects. The coefficient of the "post-reform indicator for any state-level reform" is positive and highly significant. Becoming the host of a SEZ increases the

[8]Including the year of the reform in the dummy does not alter the baseline results significantly.

average GDP level of the treated city by 19% in post-reform years. In contrast, the effect of province-level reforms is small and insignificant. In column (2) we control for the log of the city center area. This variable controls for changes in city borders, which are relatively frequent in China and would change GDP mechanically, possibly at the time of the introduction of a SEZ. The size of a city's land area has, as expected, a positive effect on GDP. Its inclusion reduces the treatment effect, but this remains large (14.7%) and highly significant. In column (3) we add the log population of the city center as a further control. Population has, as expected, a positive coefficient, and its inclusion causes land area to lose explanatory power. The treatment effect falls slightly but remains large (12.7%) and highly significant. Finally, in column (4) we use GDP per capita as our outcome variable. The estimated reform effect is now 11.7%, highly significant. In columns (5)–(8) we repeat the analysis for the sub-sample of inland provinces. In this sub-sample, cities were granted the status of SEZ on the basis of administrative criteria, such as being a provincial capital.[9] This is an interesting sub-sample since it involves less selection, as discussed above. To mitigate selection concerns even further, we exclude from the inland sub-sample cities that were granted the status of SEZ in spite of not being provincial capitals. Thus, the restricted inland sample only contains provincial capitals (treatment group) and cities that were never granted the SEZ status (control group). Columns (5)–(8) in Table 2.3 show that the results are largely robust to this sample restriction.[10] The coefficient of interest is positive and significant, and even larger than in the total sample.

2.4.2 Pre-reform Trends

A concern with the results of Table 2.3 is that cities hosting SEZ might already have been on a higher-growth trajectory – or might even have been selected precisely because of their promise of success. The focus on inland capitals alleviates such concerns. However, the year in which capitals were assigned to the treatment group may not be random. Moreover, provincial capitals may be a special group *per se*.

We address this point through two strategies. First, we investigate whether the performance of treated cities was different from that of other cities in the same province in the

[9]In the sub-sample of inland cities, 44 cities were granted SEZ status. Of these, 18 were provincial capitals.

[10]Arguably, inland capitals is *per se* a special group. Since the selection of treated cities was based on an administrative criterion (rather than on unknown, possible heterogenous criteria), we can control for features making capital cities different from the control group, such as infrastructure and education, and allow the treatment effect to depend interactively on such features. In a regression not reported, available upon request, we find that including these interactions does not alter significantly the main treatment effect which remains in all cases highly significant. The only significant interaction effect is that with the number of universities, whose sign is positive.

years shortly pre-dating the reform. Table 2.4 is the analogue of Table 2.3, reporting the results of regressions where we add four pre-reform indicators taking on the unit value, respectively, in the year of reform and one, two and three years before the reform.[11] If cities were granted the status of SEZ due to their promising pre-reform trends, these coefficients ought to be positive and significant. In contrast, we find the estimated coefficient of the pre-reform dummies to be insignificant, and often negative. The treatment effect instead continues to be positive and significant, except in columns (7) and (8), where it turns marginally insignificant. It is useful to note that the point estimates in the restricted sample (including those that are not statistically significant) are similar to those in the full sample, although estimated less precisely. In summary, the results of Table 2.4 are reassuring, and suggest that there were no important differences in pre-reform economic performance between treated cities and the control group.[12]

Second, we consider a more flexible specification allowing treated cities to have different time trends from the non-reformers. This addresses the potential worry that in our baseline specification the positive effect of SEZ might arise spuriously due to the omission of pre-existing trends. The new specification allows the GDP of cities that host, at some point, a SEZ to have a linear time trend that differs from the control group's already before the reform. In some specifications, we even allow this trend to undergo a structural break at the time when the reform indicator switches on. More formally, we consider the following specification:

$$\begin{aligned} y_{ipt} &= \phi_i + \gamma_{tp} + \alpha_1 I\_Reform_{it} + \alpha_2 \left[(t-1987) \times I\_Reformer_i\right] \\ &+ \alpha_3 \left[\max\left\{0, (t - ReformYear_i) \times I\_Reform_{it}\right\}\right] + X_{it}\beta + \varepsilon_{it}, \end{aligned} \tag{2.2}$$

where, as above, I_Reform_{it} is an indicator switching on in the first year after the reform. Moreover,

- $I\_Reformer_i$ is a dummy identifying cities that were reformed at any time. $t \geq 1988$ denotes the year of the observation. Therefore, α_2 captures the steepness of a linear trend specific to reformers, i.e., how many percentage points the growth rate differs between reformers and non-reformers.

[11] We also explored longer lags. There is evidence of some marginally significant effects at the five-year lag. However, lags longer than three years are identified out of a significantly smaller set of reforming cities (since many cities were granted the SEZ status in the early 1990's, and our sample only starts in 1988). For instance, in the full sample the first three lags are identified out of 73 to 75 cities, while the fifth lag would only be identified out of 27 cities. In the restricted sample, the first three lags are identified out of 18 cities, whereas the fifth lag is only identified out of 3 cities.

[12] Note also that the earliest zones ("comprehensive SEZ") introduced before 1989, likely the most selected group, are either excluded or exhibit no time-variation in the policy indicators in our sample period. Thus, they play no role in the identification of the treatment effect.

- $ReformYear_i$ is the year in which the first SEZ was introduced in city i (if a city never became a SEZ, then we let $ReformYear_i = 0$). The interaction

$$[(t - ReformYear_i) \times I\_Reform_{it}]$$

allows a differential trend (i.e., a trend break) starting as of the introduction of the first SEZ. The coefficient α_3 measures the steepness of such a trend break.

- α_1 captures a level shift as in the baseline specification of equation (2.1).

The results for the full and restricted (inland) samples are shown in Table 2.5, columns (1)-(4) and (5)-(8), respectively. We build here on the specification of columns (3) and (7) in Table 2.3, including all control variables (whose estimated coefficients are not reported, for simplicity). The results are robust to the other specifications presented in Table 2.3. Columns (1) and (5) of Table 2.5 simply reproduce for convenience columns (3) and (7) in Table 2.3, respectively. In the regressions of columns (2) and (6) we add a linear trend specific to reformers. The estimated coefficient $\hat{\alpha}_2$ ("time trend of reformers (state-level)") is statistically significant in both the full and the restricted sample. Interestingly, the coefficient $\hat{\alpha}_1$ continues to be highly significant in the full sample, although much of the effect is now absorbed by the trend. However, it becomes marginally insignificant in the restricted sample. The trend in columns (2) and (6) does not distinguish pre- and post-reform periods. Thus, in columns (3) and (7) we allow a structural break in the trend of reformed cities, by including $\max\{0, (t - ReformYear_i) \times I\_Reform_{it}\}$ in the regression. Interestingly, the estimated coefficient $\hat{\alpha}_1$ remains almost unchanged in the full sample and increases slightly in the restricted sample. Moreover, the estimated coefficient of the pre-reform trend, $\hat{\alpha}_2$, is small and only marginally significant in the full sample, while it is insignificant in the inland sample. The post-reform trend, $\hat{\alpha}_3$, is insignificant in both samples. Altogether, the statistical specification studied so far suggests that the baseline model with a GDP level shift performs better than one allowing for a trend break implying a permanent GDP divergence between the treatment and control groups.

The specification of columns (2)–(3) and (6)–(7) – allowing for permanently diverging paths – may be too extreme. We consider, then, an alternative specification allowing SEZ to have a non-linear effect of the SEZ relative to the pre-reform trend. To avoid an overparameterization, we omit the level shift, and we estimate the following alternative econometric specification:[13]

$$\begin{aligned} y_{ipt} &= \phi_i + \gamma_{tp} + \alpha_2 \left[(t-1987) \times I\_Reformer_i\right] \\ &+ \alpha_3 \left[\max\{0, (t - ReformYear_i) \times I\_Reform_{it}\}\right] \\ &\quad + \alpha_4 \left[\max\{0, (t - ReformYear_i) \times I\_Reform_{it}\}\right]^2 + X_{it}\beta + \varepsilon_{it}. \end{aligned} \tag{2.3}$$

The regression results from this specification are provided in columns (4) and (8). In both cases, we find that $\hat{\alpha}_3 > 0$ and $\hat{\alpha}_4 < 0$, implying that the SEZ are associated with an acceleration of growth in the immediate post-reform years, but that the acceleration dies off in subsequent years. The coefficients are both individually and jointly statistically significant. Interestingly, in the full sample there continues to be some evidence of a positive pre-reform differential trend for reformers. In contrast, in the restricted sample of inner cities we find no such evidence (the estimated coefficients $\hat{\alpha}_2$ turns negative and totally insignificant). This suggests that the government might have picked winners in the full sample, but not in the restricted inland sample. In summary, this specification suggests that the effect of SEZ is a significant gradual increase in the GDP level, rather than a permanent increase in growth (i.e., a *linear* trend break of the treated cities after reforms).[14]

2.4.3 Lagged Effects of SEZ

Motivated by the findings in the previous section, we now perform a non-parametric analysis of the effects of the reform with the aid of a model that imposes no functional form restrictions on post- (and pre-) reform effects. All effects are captured by separate lag- or lead-specific dummies. More formally, we run the following regression:

$$y_{ipt} = \phi_i + \gamma_{t,p} + \sum_{n=-J_B}^{J_F} \alpha_n I_{it}^n \{(t - Reformyear_i) = n\} + X_{it}\beta + \varepsilon_{it},$$

where positive values of $t - Reformyear_i$ measure how many years before year t city i became the host of a SEZ. Negative values measure how many years ahead of t city i will be reformed. Note that this specification allows us to identify some of the lagged effects out of reforms that took place before 1988. For instance a city that hosted its first SEZ in 1986 will have variation for all leads ranging from 2 to 24 years. In our baseline specification,

[13]It would be possible to include also the term $\alpha_1 I\_Reform_{it}$ to this specification. However, it is very difficult to identify separately all the effects in such a highly parametrized model. Therefore, we omit this term, and regard the current specification as a non-nested alternative to equation (2.2).

[14]Clearly, the quadratic model is not a correct specification itself, since it would imply a negative long-run effect of SEZ. Given the short sample, the data only capture the increasing part of the quadratic relation. See the next section for a more general specification.

instead, such a city would display no within variation, and the reform indicator would be collinear with the city fixed effect. In our sample, the maximum number of post-reform leads, J_F, is 26, corresponding to a single city which hosted its first SEZ in 1984. We construct these indicators also for the year of reform and the three years prior to the reform (i.e. $J_B = 3$), so we can test whether reforming cities already had a significantly different performance prior to the establishment of the first zone.[15] The omitted categories (for which all indicators are zero) are never-reforming cities and cities more than three years before the reform. The controls include land area, population, and the usual set of fixed effects.

The results are displayed in Figure 2.3, showing the lead and lagged effects of the treatment n years past the reform (for instance, n=10 measures the effect ten years past the introduction of a SEZ). This specification confirms the results of the previous section. In particular, there is a break in the GDP path a year after the reform, followed by a temporarily higher growth rate that levels off after about ten years. The size of the effects are comparable to those in the previous section.[16] There is only some marginal, statistically insignificant evidence of a higher GDP growth in the three years before the reform, indicating some minor positive selection. Note that the standard errors increase after nineteen years after the establishment of the zone (corresponding to the vertical line added to each figure). This is due to a significant drop in the number of observations, since many cities were reformed in 1991 and 1992.[17]

We estimate the same regression for the restricted sample of inland provinces (excluding cities which had a reform but are not provincial capitals), see Figure 2.4. The qualitative pattern and the point estimates are similar, although the estimation is less precise, and only the effects 9-12 years after the reform are statistically different from zero.[18] In section 2.5.7, we show that if residuals are clustered at the province×years of reform (instead of city) level, the effects 7-18 years are statistically significant in the inland sample.

[15] For the same reasons described in the discussion of Table 2.4, we do not include more pre-reform indicators. When we include also indicators for four and five years prior to the reform, these indicators are marginally significant, but identified by only 27 observations.

[16] The average over the yearly estimates (weighted with the number of observations identifying each estimate) of all post-reform indicators is 17.1%, which is even somewhat higher than the result in the simple regression in Table 2.4.

[17] When the cities reformed in 1991 and 1992 reach the year 2010, the subsequent number of cities that identify the individual coefficients drops from 54 to 9. The vertical dashed line in the figure marks this drop.

[18] The reforms in the inland provinces started almost a decade later than in the coastal provinces. The post-reform effects are therefore estimated for a shorter period and based on fewer observations.

2.4.4 Different Types of SEZ

In this section, we attempt to disentangle the effects of the different types of SEZ which had distinct policies. To this aim, we create separate post-reform indicators for each of the three most important (and most common) SEZ: ETDZ, HIDZ and EPZ. In addition, we create a single dummy for other types of state-level SEZ. Table 2.6 has the same structure as Table 2.3 but replaces the indicator for "any" state-level zone with the four separate indicators for each type of state-level SEZ. ETDZ and HIDZ appear to have a large effect. In the full sample, the effects of these two types of zones are quantitatively similar to those of the first zone in Table 2.3. In the inland sample, there are two deviations. First, the point estimate of ETDZ remains positive but becomes insignificant when the dependent variable is GDP per capita. Second, the OtherTypes have in two cases a higher estimate than ETDZ and HIDZ, although these results are driven by very few observations.[19] EPZ are insignificant throughout, although the coefficient is positive in seven out of eight cases. Overall, the disaggregation highlights the relative importance of the ETDZ and HIDZ, which are the two largest and most comprehensive types of zones in our sample, as well as those emphasizing most explicitly technology development aspects.

The regressions with simple post-reform indicators for the different types of zones is restrictive in the sense that it assumes a jump in the GDP level after the reform. Since we have seen that the effects of "any" zone build up gradually during about ten years and then level off, we investigate whether the same pattern holds true for the individual types of zones. Since the pre- and post-reform effects of different types of zones often overlap (treated cities often had multiple zones of different kinds), the approach in section 2.4.3 is quite demanding. Nevertheless, the resulting picture is reasonably clear. Figure B.1, which can be found in the appendix, plots the coefficients of the different types of zones (estimated in the same regression) over the years since reform. The first panel shows that the pattern for ETDZ looks remarkably similar to that of Figure 2.3 (first zone reformed). The second panel shows that HIDZ also display a concave pattern, although the effect appears to decline after lag 10.[20] EPZ and OtherTypes show a more mixed picture (the two lower panels in Figure B.1).[21] The standard errors are very large and the effects typically are imprecisely estimated and statistically insignificant. In summary,

[19] 14 cities have a zone type other than ETDZ, HIDZ, or EPZ, but in 11 of these the zone this is in conjunction with an ETDZ or HIDZ.

[20] There is a sharp (statistically insignificant) drop in the last lag (19). This may be due to the changing sample size, as the number of cities identifying this last coefficient drops discontinuously by more than half in this period.

[21] The stark drop in OtherTypes is identified by only one observation. EPZ were established after 2000 and often inside an existing zone. Furthermore, the EPZ may have gained importance after the WTO accession in 2001, which could explain their upward trend (though insignificant).

most development effects appear to stem from ETDZ and HIDZ.

2.4.5 Decomposing the Effects of the SEZ

In the previous sections, we document that the establishment of SEZ has a positive effect on GDP at the city level. In this section, we investigate the channel through which the zones promote growth. To this aim, we decompose GDP per capita into the following input factors: physical capital per capita, human capital and TFP. We then estimate how the establishment of a SEZ affects each of the three components.

Following Hall and Jones (1999) and Caselli (2005), we perform a level-decomposition exercise based on the standard Cobb-Douglas production function $Y = AK^{\alpha}(hL)^{1-\alpha}$. More formally,

$$\begin{aligned}\log \frac{Y_{ipt}}{L_{ipt}} &= \log A_{ipt} + \alpha \log \frac{K_{ipt}}{L_{ipt}} \\ &\quad +(1-\alpha)\log h_{ipt}\end{aligned} \tag{2.4}$$

where A denotes total factor productivity, $\frac{K}{L}$ the physical capital per capita, and h the human capital. We use the local population size to proxy the size of labor force and use the average educational attainment of the population to proxy the human capital. The details can be found in the appendix.

In Table 2.7, we display the results of baseline difference-in-difference regressions analogous to those performed in section 2.4.1, where each of the components of the decomposition equation 2.4 is used sequentially as the dependent variable. Column (1) shows that the establishment of a SEZ has a significantly positive effect on GDP per capita. Becoming the host of a state-level SEZ is associated with a 13.8% increase in the city's GDP per capita relative to non-reformed cities in the same province. When restricting the sample to inland cities, we find the effect on per capita GDP to be 13.1% and also highly significant, as shown in column (5). The estimated effect on the capital-labor ratio is displayed in column (2) and column (6). Column (2) suggests that becoming a host of a state-level SEZ increases the physical capital per capita of that city in the full sample by 14.8%. The effect on the capital labor ratio is more prominent in the inland sub-sample, as shown in column (6) – the point estimate is 24.4% and highly significant. The estimated effect on TFP in the full sample is 8.3% and highly significant. On the contrary, the SEZ seems to have a smaller (4.4%) and insignificant effect on TFP in the inland sample (column (8)). The SEZ does not have a significant effect on human capital in either of the two samples (column (3) and (7)).

Taking these results at face value suggests that the establishment of SEZ has a major positive effect on investments and leads to capital deepening. The capital deepening effect is more prominent in the inland sample while the full sample shows a more balanced picture of development, where both the capital-labor ratio and TFP experience significant increases after the establishment of a state-level zone.[22] There is no selective migration effect, i.e., the SEZ do not seem to attract better educated workers.[23]

One important *caveat* here is that the quality of the data on human capital is low. The only data available at the city-level for education attainment are from the *population census*, which are ten years apart from each other. During our sample period, three *population census* took place, in the years 1990, 2000 and 2010. Between the census years, we must resort to an interpolation. This reduces the accuracy of our measures of human capital and TFP.

The results on human capital are somewhat different if one evaluates the effects of SEZ by using only the three years for which direct observations of the education attainment are available from the census data. Rather than aggregating the existing information to obtain an estimate of the average years of schooling, we study the effect of SEZ on the share of each educational attainment level for which data are available. This yields a better sense of the impact of the policy on the distribution of human capital in the population. The results are shown in Table 2.8. Columns (1) and (2) suggest that after changing to SEZ status, the average years of schooling in the city increases by 0.17 years in the full sample and 0.23 years in the restricted (inland) sample.[24] Columns (3) and (4) show that establishing a SEZ has no impact on the share of the population with a low educational attainment (elementary degree or less). Second, SEZ appear to decrease significantly the share of the population with junior and senior high school degrees (columns 5-6). Finally, the share of college graduates in the whole population increases significantly by 3.1% and 3.8%, respectively, in the full and inland sample (columns 7 and 8). In summary, the main finding is that the establishment of SEZ is associated with an increase in the share of college graduates, at the expense of the share with intermediate education.[25] This

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[22] However, as argued in Klenow and Rodrigez-Clare (1997) and others, the increased capital-labor ratio should be attributed to increased TFP.

[23] Note that our specification seeks to identify differential improvements in TFP in cities with SEZ compared to cities without SEZ. Other studies that investigate the differential effect of SEZ include Schminke and Van Biesebroeck (2013) and Wang (2013). Schminke and Van Biesebroeck (2013) find that after controlling for selection bias, the firms that are located in the zones do not achieve significantly higher TFP than firms outside of the zones. Wang (2013) finds an effect of SEZ on TFP growth after a lag of six years. It should be noted that TFP on average may still be increasing even if there is no differential effect for SEZ. For example, Brandt and Zhu (2010) found that increases in TFP in non-state non-agricultural firms contributed significantly to growth.

[24] Ideally, we would want to compute the educational attainment of the working population (age 25-64). Unfortunately, we are unable to do so because the population census only reports educational attainment for the population over the age of 6.

[25] In an alternative specification, we bundle senior high school together with college graduates while leaving junior high school graduates as the middle level category and find a similar result: the share of

may be due either to selective immigration (i.e., cities with a SEZ attracting more highly educated immigrants) or to stronger incentives for locals to obtain higher education.

Figures 2.5, 2.6, and 2.7 display the reform effect on GDP per capita, physical capital per capita and TFP over time. The specification employed here is the analogue to that of Figure 2.3. The pattern for GDP per capita in Figure 2.5 is very similar to that of GDP in Figure 2.3. The path of GDP per capita shows a structural break one year after the reform. GDP per capita grows at a temporarily higher rate for about 10 years and remains at a permanently higher level afterwards. We see a similar concave post-reform path for physical capital per capita in Figure 2.6. The path of physical capital per capita also breaks one year after the reform and only becomes statistically significant 5 years after the reform, presumably because it takes time to build up the physical capital. After 19 years, as observed before, the effects are estimated very imprecisely. The path for TFP also features a break one year after the reform takes place and the break becomes significant 6 years after reform. The effect on TFP becomes insignificant 16 years after the reform (see Figure 2.7).

2.5 Robustness

In this section we perform robustness analysis. First, we test whether there is evidence of negative or positive spillovers to neighboring locations. Second, we repeat the baseline regressions using alternative proxies for GDP. Third, we test the robustness of the results to the inclusion of additional control variables and years. Fourth, we perform a variety of placebo exercises. Finally, we consider alternative clustering strategies.

2.5.1 Local Spillovers

We have focused so far on the main urban center (labelled as the "city") of each prefecture which is the area where *all* state-level SEZ in our sample were established. Recall that the urban center is a subset of the prefecture, that also include a large peripheral area comprising smaller cities, towns, villages and rural areas. In this section, we investigate the existence of local spillovers by studying whether the policy has any effect on the area surrounding the main urban center. To this aim, we re-run our baseline regressions of section 2.4.1 using as the dependent variables, first, the GDP of the entire prefecture (Panel A of Table 2.9); and then the GDP of the prefecture's periphery, i.e., the whole

junior high school decreases significantly and the share of senior high school and college graduate increases significantly.

prefecture excluding the city (Panel B of Table 2.9).[26] Panel A shows that the effects at the prefecture level are of comparable magnitude to those obtained for the city only. Panel B shows that the results hold up when we consider only the periphery of the prefecture.[27]

The results of this section suggest that the positive effects of the SEZ did not come at the expenses of surrounding areas. Rather, it looks as if the SEZ brought positive spillovers to the periphery of the prefecture of which the host city is part. However, our analysis cannot rule out negative spillovers across prefectures.

2.5.2 Satellite light as an Alternative Measure of GDP

Chinese price-level data are generally regarded as problematic, especially at the local level. Our empirical methodology has the advantage of not relying on any price deflator. Differences in price levels are filtered out by city fixed effects, whereas province-time fixed effects filter out cross-province inflation differentials. Yet, one might worry that cities within each province might have experienced different inflation rates. In particular, our estimated treatment effect would be biased upwards if the establishment of a SEZ systematically brought about higher inflation. As discussed above, the fact that the existing price data do not suggest that the establishment of a SEZ is associated with higher inflation is reassuring in this respect. However, one might also worry that the local authorities could over-report the *nominal* GDP of treated cities, in order to meet the expectation of the central government regarding the performance of SEZ.

To address these issues, in this section we use light intensity measured by weather satellites as an alternative proxy for GDP. A number of recent papers have argued that light intensity at night measured by weather satellites can be used as a proxy for GDP.[28] Most economic activities such as production, transport, and consumption produce light as a by-product. Therefore, light intensity is positively correlated with the intensity of local economic activities. We calculate the average light intensity within the geographical boundaries of cities and use this as a proxy for economic activity. In column (1) of Table 2.10 we re-run our baseline regression with the logarithm of the average light intensity as the dependent variable.[29] Unfortunately, light intensity is only available since 1992,

[26]On average, the GDP of the prefecture (including the city) is about twice as large as that of the city only. The size of the population of the prefecture is about four times as large as that of the city, and the size of the land area is about eight times as large.

[27]Land area and population are adjusted accordingly. There is a small drop in the number of observations, since in some cases the city coincides with the prefecture, and thus there is no periphery.

[28]Elvidge *et al.* (1997) are among the first to discuss the relationship between light and economic activity. See also Henderson *et al.* (2012) and Chen and Nordhaus (2011) and the literature cited there on the use of light to measure economic activity. Ma *et al.* (2012) and Hälg (2012) discuss the use of light data in Chinese prefecture-level cities.

[29]We do not control for the size of the land area in the regressions in columns (3) and (4) because light

and only one-third of the (first) SEZ were established after that year. Moreover, even for later reformers we lose annual observations that would be useful for a precise estimation of the within-city effect of SEZ establishment. The loss of precision is confirmed by the observation that if we run the baseline regression of section 2.4 with GDP as the dependent variable for the post-1992 period we obtain a point estimate of 0.042, statistically insignificant. Yet, when GDP is proxied by satellite light, we find that the establishment of a SEZ triggers a 5.2% increase in light intensity. The point estimate for the inland sample is similar in magnitude, albeit statistically insignificant.

We also check the robustness of our results by using electricity consumption as a proxy of economic activity (see, e.g., Rawski 2001). Data on electricity consumption by households and firms are reported in the same statistical yearbooks as GDP, and is available at the city level. In column (3) of Table 2.10 we re-run our baseline regression using the logarithm of electricity consumption as the dependent variable. The result shows that the establishment of a SEZ is associated with an 11% increase in electricity consumption. The raw elasticity of GDP with respect to electricity consumption in our sample is 0.91, such that the estimated effect would translate into a 10% increase in the GDP level.[30]

2.5.3 Controlling for Government Spending

The establishment of a SEZ is likely to have been associated with a number of policy changes from the central and local governments. Most notably, the central or the provincial government may increase the transfers to cities when these are granted SEZ status. Unfortunately, we have no direct information on such transfers. SEZ may have also triggered government investments in infrastructure. The effects identified in the previous sections are gross of such investments. On the one hand, the infrastructure investments are part of the government's strategy to facilitate economic development and therefore are part of the treatment. On the other hand, one may be interested in estimating the net effects after controlling for changes in public investments.

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is measured within the city boundaries of 2010. Therefore, unlike for the official GDP data, the area on which we measure economic activity is held constant over the years.

[30]However, we find no significant effect in the inland sample. We suspect that this is due to the poor quality of electricity data in this subsample, for which we have no explanation. We calculated the correlation between GDP (data) and electricity separately in four sub-samples: inland reformers, inland non-reformers, coastal reformers and coastal non-reformers. The correlation is high and significant in all subsamples except for that of inland reformers where the elasticity of GDP with respect to electricity is very low (0.02) and statistically insignificant. Interestingly, the correlation between GDP (data) and satellite light intensity is instead consistent and significant across the four sub-samples, suggesting that the source of problems is not the GDP statistics, but rather the electricity data.

While we have no information on public investments at the city level, we do observe the overall expenditures of the local government for a subset of the years in our sample. This measure can be used as a proxy of the contribution of public investments to GDP. The disadvantage of including the local government expenditure is twofold. First, we lose some observations. Second, causation could run in the opposite direction: government expenditure might have increased because the GDP expansion caused by the SEZ increased the tax revenue accruing to the local authorities.

Table 2.11 shows that the reform effects are robust to the inclusion of government expenditure among the control variables. The effect of the reform remains positive and highly significant in both samples, and is in fact larger than the point estimates in Table 2.3.

2.5.4 Earlier GDP Data

Our main analysis focuses on the period 1988-2010 for which the NBS provides a consistent measurement across cities and years. This conservative approach entails the cost of losing variation in the reform variable, since some SEZ were established before 1988. We re-estimate our baseline specification for a subset of cities for which GDP is also available for earlier years.[31] In this case, we cannot control for changes in land area, government spending and population as this data is missing for the earlier years. The reform effect estimated with this subsample is a 12.3% increase in the level of GDP, and the estimated coefficient is highly significant.

2.5.5 Population Data

In our analysis so far, we have used the population data from the City Statistical Yearbooks. To the best of our knowledge, these data cover only the registered population in the city, that is, people with "*hukou*". The existence of a large number of non-resident immigrant workers in the cities could potentially bias our estimation. To address this issue, we check first the CSY statistics against the population census that in principle should record the entire resident population at the city level. However, as noted above, census data are only available for three years (1990, 2000 and 2010) in our sample. We find that there is a gap between the two data sources. In particular, if the census is right, the population growth rate is overestimated by an annual 0.24% in non-reforming cities, and underestimated by 0.35% in reforming cities in the city statistics. The observation that the population is underestimated in the treatment group and overestimated in the

[31]Namely the cities in the following provinces: Fujian, Guizhou, Hebei, Heilongjiang, Henan, Inner Mongolia, Jiangsu, Shaanxi, Shandong and Shanxi.

control group is not surprising, as the treatment cities are likely to have attracted many *non-hukou* workers from the control group.

To test the robustness of our baseline results, we repeat the baseline regressions of Table 2.3 restricting our sample to the three census years and using population census data instead of population CSY data. Columns (1)-(2) and (5)-(6) of Table 2.12 simply replicate the results in Table 2.3 in the restricted sample. In column (3) and (7) of Table 2.12, where population is used as a control variable, the estimated effect of SEZ is found to be highly significant and of similar magnitude to that of the baseline specification in Table 2.3 (although the estimated coefficient drops from 0.18 to 0.13 in the inland sample). In the specification using output per capita as the dependent variable (column (4) and (8)), the effects of SEZ on per capita GDP are somewhat smaller than in the corresponding columns of Table 2.3 (the effect being 8% and the full sample and 10% in the inland sample). The estimates continue to be statistically significant, albeit only at the 95% confidence level in the full sample and at the 90% confidence level in the inland sample. It is important to note that by restricting the sample to only three years, we lose precision in the time variation of the treatment effect.[32] This could explain part of the reduction in the estimated treatment effect. In addition, the estimates including *non-hukou* workers should be regarded as a lower bound of the effect, since these workers on average carry a lower human capital than officially resident workers. All in all, our baseline results appear to be robust to using the resident population data from the census.

2.5.6 Placebo Analysis

Our estimation exploits the time and spatial variation in the establishment of SEZ. Since the establishment of the SEZ is staggered, but clustered in few years, there could be concern about the extent to which the exact timing of the reform matters for the identification of the reform effect. Furthermore, we would like to rule out that our reform indicators pick up shocks unrelated to SEZ that could be present also in other cities. In order to deal with these concerns, we run three placebo exercises based on the specification in column 3 of Table 2.3, but assign reform years randomly.

In a first exercise, we assign the actual number of new zone establishments in each year to a random selection of cities. The resulting placebo distribution is the same as the true distribution over time, but SEZ are assigned artificially to random cities. We repeat this exercise 1000 times. We find that in no case are the absolute t values and the

[32]Consider, for instance, columns (5)-(6), which involve no population data. The estimated coefficients in Table 2.3 are 0.27 and 0.21, respectively, whereas the corresponding coefficients in Table 2.12 are 0.22 and 0.15, repectively.

R-squared of the placebo regressions larger than those of the true reform.[33] This suggests that the spatial distribution of SEZ indeed drives our result.

In a second more demanding placebo test, we assign the random reforms only to reformers, again holding the distribution of reforms across years constant. However, the timing of the treatment is scrambled across cities. This allows us to assess the extent to which the time dimension of the reform matters, because we are only randomizing the year of the reform but not the treated city. We find that the absolute t-values are higher when using the year of the true reform than in the placebo regressions in all but 1.8% of the cases.[34] This indicates that the actual year in which the SEZ were implemented is critical for our results, and supports our identification strategy based on within-city variation.

Finally, we use the random assignment of reforms from above and include the true reform year and the placebo reform year in the same regression.[35] While the estimate for the true reform is always significant at 5%, the placebo reforms are significant in only 24% of the cases.[36] Overall, these placebo exercises strengthen our confidence in the empirical strategy used. Both the spatial and the time variation of the SEZ appear to be important for the results.

2.5.7 Alternative Clustering Strategies

In our main analysis we cluster standard error at the city level, to allow for observations within a given city to be correlated as well as for heteroskedasticity. Our results are robust to alternative clustering strategies. First, we cluster the standard errors by province and year of reform (i.e., the first year in which a city hosts a SEZ). This strategy takes account of the fact that the introduction of SEZ is highly clustered in time. Many HIDZ were introduced in 1991–92, and many ETDZ were introduced in 2001–03, implying that different cities in these years cannot be treated as independent observations. The results are essentially unchanged. Appendix Tables B.1-B.2-B.3-B.4-B.5 and appendix Figures B.2-B.3 yield the analogues of Tables 2.3-2.4-2.5-2.6-2.7 and of Figures 2.3-2.4 under the alternative clustering strategy. The results are robust: the statistical significance of the coefficients of interests is even strengthened, and in a few cases coefficients that

[33]The mean estimate of the placebo reform is -0.0004 and it is never significant and higher than the one of the true reform.

[34]The mean estimate of the placebo reform is 0.088. The placebo specification yields significant coefficients in only 5% of the draws. It yields higher point estimates than the specification with the true reform year in 5% of the draws.

[35]The assignment of random reform years among reformers implies that a placebo reform year is likely to coincide with the true reform year. This is the case in 36% of the 1000 draws.

[36]The mean estimate of the true reform is 0.11 and the mean estimate of the placebo reform is 0.046.

were marginally insignificant when clustering at the city level turn significant here. Most notably, this is the case of appendix Figure B.2, the analogue of Figure 2.3, capturing the lagged effect of reforms in the inland sample.

We also run the regressions clustering standard errors at the province level (instead of province×year of first reform). This strategy is even more demanding, and runs into potential problems since we have only 28 provinces in the full sample and 18 provinces in the inland sample, and so the number of clusters is small. The results are robust to even this demanding approach. The coefficients of interests in appendix Tables B.6-B.7-B.8-B.9-B.10 and the lagged reform effects in appendix Figure B.4-B.5 remain significant with 2 exceptions, both of which occur in specifications using the inland sample.[37]

2.6 Conclusion

China has experienced an astonishing economic development over the past 30 years. The SEZ are a building block of the development strategy pursued by its government. According to Naughton (2007): "Bold, fragmented, open to outside investment, but with a strong role for government: Special Economic Zones typify much of the Chinese transition process" (p. 410). This paper estimates the effect of SEZ on local economic performance. We considered a number of specifications that control for unobserved heterogeneity at the city level and at the province-time level. The results suggest that the establishment of SEZ has yielded large positive effects for the cities in which these were located. Although our estimates are smaller than those found by the earlier literature based on cross-sectional growth regressions (typically on a smaller set of cities and years), the effects are sizeable and robust. We also find that the effect of the SEZ on output worked mainly through the acceleration of physical capital investment – although there is some indication of positive effects on TFP and human capital accumulation.

What can we learn from the Chinese experience about the role of economic reform and industrial policy during the process of development? Existing theoretical and empirical work suggests that policies and institutions should be "appropriate" to the stage of development, and particularly to the stage of the process of technological convergence (Acemoglu *et al.* 2006). The Chinese reform process was characterized by a mixture of elements of market liberalization and an active role of government in promoting investment and technology adoption. Rodrik (2006) argues that the active role of the government was crucial for China's development because it supported a fast move towards more modern and productive sectors which have positive externalities on the whole economy. The

[37]The exceptions are: policy indicators of state-leve zone in column (7) of Table B.8 and column (7) of Table B.9.

results of our empirical analysis suggest that the industrial policy may have indeed been a catalyst of the development process. At the same time, the estimated effects are not quantitatively very large relative to the high growth rates experienced by China in this period. Therefore, it would be hazardous to conclude that SEZ were *the* most important component of the reform package. Two limitations to recall are that (i) we cannot quantify the costs of the policy, and thus the judgment about the welfare effects of SEZ must remain suspended; (ii) by design, our methodology can only uncover differential effects. If the establishment of SEZ had positive spillovers outside of the areas where they were introduced, our estimates represent a lower bound of the actual effects. In spite of these limitations, we believe that our results provide a useful starting point for a realistic understanding of the effects of industrial policy in China.

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2.8 Tables

Table 2.1: State and Province Level Zones in 3 Provinces

Province	#S	#P	Avg indus-output share of S	Avg indus-output share of P
Jiangsu	12	113	3.13%	0.55%
Guangdong	14	56	4.89%	0.56%
Zhejiang	8	57	4.09%	1.18%

Source: WEFore (2010). The table displays the number of state level development zones (#S) and province level development zones (#P) in three provinces: Jiangsu, Guangdong and Zhejiang. In the last two columns, it also displays the average share of the state level and province level zones in the industrial output of each province. The data is for the year 2009.

Table 2.2: Descriptive statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Real GDP (mil)	10388.9	21776.23	116.62	414700.53	5147
Growth of real GDP (%)	13.07	18.13	-52.19	594.78	4738
Land area (sq km)	1728.36	2028.58	25	20169	5159
Growth of land area (%)	8.44	170.69	-93.23	9852	4750
Population (mil)	1.01	0.87	0.1	8.01	5275
Growth of population (%)	2.71	17.97	-77.18	586.19	4876
Electricity consumption (GWh)	3.08	4.71	0.01	56.3	5085
Growth of electricity consumption (%)	17.41	202.25	-98.97	13486.34	4674
Mean light intensity (calibrated)	13.32	11.27.4	0.12	64.38	4435
Growth of light intensity (calibrated) (%)	5.22	13.98	-38.93	124.57	4178

The table shows the descriptive statistics of our main variables in our sample of 276 cities in 25 provinces. Real GDP is derived from city-level nominal GDP and provincial deflators. Land area is the offical size of the prefecture level cities. Population includes registered residents only. Electricity consumption is by households and firms. Mean light intensity is the average brightness of pixels in the city.

Table 2.3: Baseline specification

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.190***	0.147***	0.127***	0.117***	0.268***	0.212***	0.181***	0.166***
	(4.56)	(4.29)	(4.43)	(4.15)	(4.87)	(4.12)	(3.51)	(3.09)
Post-reform indicator for province-level zone	-0.000486	-0.00706	0.000497	0.00412	-0.0157	-0.0244	-0.00775	0.00319
	(-0.02)	(-0.31)	(0.02)	(0.20)	(-0.55)	(-0.89)	(-0.28)	(0.11)
Log landarea		0.240***	-0.0325	-0.154***		0.211***	-0.0533	-0.175***
		(7.73)	(-1.18)	(-7.66)		(5.84)	(-1.22)	(-5.49)
Log population			0.692***				0.673***	
			(12.22)				(7.38)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2554	2686	2686
AR2	0.960	0.969	0.975	0.964	0.961	0.965	0.971	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table 2.4: Pre- and post-reform indicators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indicator for 3 years before any state-level zone	-0.00764	0.0247	0.0229	0.0221	-0.00543	0.00564	-0.0172	-0.0283
	(-0.22)	(0.71)	(0.82)	(0.81)	(-0.06)	(0.06)	(-0.21)	(-0.30)
Indicator for 2 years before any state-level zone	-0.0147	0.0255	0.0238	0.0230	-0.0429	-0.0221	-0.0400	-0.0487
	(-0.41)	(0.71)	(0.84)	(0.84)	(-0.50)	(-0.25)	(-0.49)	(-0.54)
Indicator for 1 year before any state-level zone	-0.0252	0.0165	0.0161	0.0159	-0.0572	-0.0367	-0.0536	-0.0618
	(-0.71)	(0.46)	(0.57)	(0.58)	(-0.64)	(-0.39)	(-0.64)	(-0.67)
Indicator for year of any state-level zone	-0.00290	0.0213	0.0232	0.0241	-0.0816	-0.0599	-0.0742	-0.0811
	(-0.08)	(0.55)	(0.74)	(0.79)	(-0.90)	(-0.64)	(-0.85)	(-0.84)
Post-reform indicator for any state-level zone	0.180***	0.165***	0.144***	0.134***	0.229**	0.188*	0.143	0.121
	(3.32)	(3.37)	(3.83)	(3.69)	(2.52)	(1.91)	(1.57)	(1.20)
Post-reform indicator for province-level zone	-0.000807	-0.00645	0.00110	0.00471	-0.0166	-0.0307	-0.00860	0.00215
	(-0.03)	(-0.28)	(0.05)	(0.23)	(-0.57)	(-1.10)	(-0.31)	(0.08)
Log landarea		0.241***	-0.0321	-0.154***		0.197***	-0.0536	-0.175***
		(7.75)	(-1.16)	(-7.63)		(5.25)	(-1.23)	(-5.51)
Log population			0.692***				0.673***	
			(12.26)				(7.39)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2686	2686	2686
AR2	0.960	0.969	0.975	0.964	0.961	0.966	0.970	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table 2.5: Trend break

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.127***	0.0825***	0.0837***		0.181***	0.0858	0.0972*	
	(4.43)	(2.84)	(2.87)		(3.51)	(1.52)	(1.89)	
Post-reform indicator for province-level zone	0.000497	0.000738	0.000861	0.00219	-0.00775	-0.00668	-0.00768	-0.00996
	(0.02)	(0.04)	(0.04)	(0.11)	(-0.28)	(-0.24)	(-0.28)	(-0.36)
Time trend of reformers (state-level)		0.00548**	0.00595*	0.00656*		0.00855*	0.00262	-0.000951
		(2.15)	(1.68)	(1.88)		(1.69)	(0.26)	(-0.09)
Post-reform trend (state-level)			-0.000747	0.0156**			0.00624	0.0450**
			(-0.19)	(2.25)			(0.53)	(2.58)
Sq. post-reform trend (state-level)				-0.000740***				-0.00182***
				(-2.60)				(-2.80)
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5141	5141	5141	5141	2686	2686	2686	2686
AR2	0.975	0.975	0.975	0.975	0.971	0.971	0.971	0.971

The dependent variable is the logarithm of annual GDP at the city level in all columns. GDP is measured in current prices. All specifications also control for the logarithm of population and land area and they include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table 2.6: Effects of different types of zones

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for ETDZ	0.220***	0.156***	0.120***	0.104***	0.239***	0.171***	0.0969*	0.0581
	(4.62)	(3.66)	(3.17)	(2.72)	(3.97)	(2.99)	(1.67)	(0.99)
Post-reform indicator for HIDZ	0.117***	0.0794**	0.0755**	0.0736**	0.122**	0.0925*	0.106**	0.113**
	(2.64)	(2.19)	(2.45)	(2.40)	(2.57)	(1.80)	(2.18)	(2.26)
Post-reform indicator for EPZ	0.0412	0.0361	0.0205	0.0131	-0.0123	0.00190	0.0490	0.0738
	(0.92)	(0.94)	(0.60)	(0.38)	(-0.15)	(0.02)	(0.64)	(1.03)
Post-reform indicator for OtherTypes	0.0710	0.0583	0.0898*	0.104**	0.0827	0.174*	0.213**	0.233**
	(0.99)	(0.93)	(1.81)	(2.21)	(1.13)	(1.67)	(2.19)	(2.45)
Post-reform indicator for province-level zone	0.00286	-0.00532	0.00260	0.00649	-0.0158	-0.0297	-0.00878	0.00223
	(0.11)	(-0.24)	(0.13)	(0.32)	(-0.56)	(-1.08)	(-0.32)	(0.08)
Log landarea		0.233***	-0.0361	-0.159***		0.187***	-0.0535	-0.180***
		(7.20)	(-1.30)	(-7.66)		(4.83)	(-1.20)	(-5.55)
Log population			0.686***				0.655***	
			(11.85)				(6.76)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2686	2686	2686
AR2	0.961	0.969	0.975	0.964	0.962	0.967	0.971	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. *OtherTypes* include BECZ, Bonded Zones, and zones of unknown type. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table 2.7: Decomposition of the effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for first state-level zone	0.138***	0.148***	0.00343	0.0825***	0.131***	0.244***	0.00409	0.0442
	(4.81)	(3.26)	(0.86)	(3.04)	(3.00)	(3.75)	(0.70)	(1.23)
Post-reform indicator for first province-level zone	-0.0127	-0.0159	0.00242	-0.0125	-0.0145	-0.0201	0.00448**	-0.00705
	(-0.74)	(-0.53)	(1.44)	(-0.64)	(-0.67)	(-0.47)	(1.98)	(-0.26)
Log landarea	-0.218***	-0.532***	-0.0157***	0.0120	-0.212***	-0.490***	-0.0157***	-0.000134
	(-6.41)	(-10.94)	(-4.58)	(0.36)	(-5.35)	(-8.97)	(-3.98)	(-0.00)
Dependent Variable	log(Y/L)	log(K/L)	log(h)	log(TFP)	log(Y/L)	log(K/L)	log(h)	log(TFP)
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5171	4521	4381	3970	3242	2744	2610	2320
AR2	0.948	0.959	0.957	0.802	0.938	0.954	0.950	0.731

The dependent variables are the logarithms of real GDP per capita column (1) and (5), and the three decomposed components: logarithm of physical capital stock (column (2) and (6)), logarithms of average human capital (column (3)-(7)) and logarithm of TFP (column (4)-(8)), of the prefecture area. All specifications include land area, city fixed effect and the interaction of province-year dummies as control variables. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regression is carried out for the full sample (column (1)-(4)) and restricted inland sample ((5)-(8)).

Table 2.8: Effect on human capital (census years only)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for first state-level zone	0.173***	0.229***	-0.00985	-0.00544	-0.0208***	-0.0321***	0.0307***	0.0376***
	(3.46)	(3.36)	(-1.58)	(-0.70)	(-2.93)	(-3.43)	(5.97)	(5.48)
Post-reform indicator for first province-level zone	0.0993***	0.133***	-0.0116*	-0.0190***	0.0103	0.0138**	0.00129	0.00523
	(2.84)	(2.87)	(-1.88)	(-2.92)	(1.62)	(1.99)	(0.35)	(1.01)
Log landarea	-0.269**	-0.194*	0.0379***	0.0221	-0.0148	-0.00191	-0.0230**	-0.0201*
	(-2.56)	(-1.76)	(2.66)	(1.53)	(-1.59)	(-0.22)	(-2.49)	(-1.97)
Log population	-0.139	-0.267	0.0180	0.0484*	-0.00665	-0.0332**	-0.0114	-0.0154
	(-0.83)	(-1.26)	(0.78)	(1.66)	(-0.44)	(-2.09)	(-0.72)	(-0.76)
Dependent variable	avg. sch.	avg. sch.	share low	share low	share mid.	share mid.	share high	share high
Sample	Full	Inland	Full	Inland	Full	Inland	Full	Inland
N	577	360	577	360	577	360	577	360
AR2	0.976	0.976	0.968	0.971	0.884	0.900	0.929	0.934

The dependent variables are average years of schooling (column (1)-(2)), share of population over 6 with low level education (primary school or lower)(column (3)-(4)), share of population over 6 with an intermediate level education (junior and senior high school) (column (5)-(6)) and share of population over 6 with high level education (college or above) (column (7)-(8)), of the prefecture area. All specifications include land area of the prefecture, pefecture fixed effects and the interaction of province-year dummies as extra control variables. T-statistics are reported in parenthesis. Standard errors are clustered at the prefecture level. The sample includes 276 cities from 25 provinces in 1990, 2000 and 2010, when the population census were conducted (unbalanced panel). The regression is carried out for the full sample (column (1), (3), (5), (7)) and restricted inland sample ((2), (4), (6), (8)).

Table 2.9: Reform effects on entire prefecture and on periphery only

Panel A: Prefecture Area

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.156***	0.118***	0.132***	0.136***	0.213***	0.186***	0.190***	0.197***
	(4.72)	(4.05)	(4.80)	(4.85)	(3.07)	(3.39)	(3.65)	(3.63)
Post-reform indicator for province-level zone	0.0236	-0.00340	-0.00858	-0.0102	0.0272	-0.00933	-0.0144	-0.0143
	(1.01)	(-0.19)	(-0.50)	(-0.60)	(0.81)	(-0.37)	(-0.61)	(-0.60)
Log landarea		0.410***	-0.0566	-0.218***		0.345***	-0.0178	-0.210***
		(12.89)	(-0.79)	(-6.35)		(5.76)	(-0.22)	(-4.58)
Log population			0.743***				0.686***	
			(7.67)				(6.04)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5403	5329	5327	5327	2871	2637	2803	2803
AR2	0.957	0.975	0.979	0.973	0.945	0.971	0.976	0.967

Panel B: Periphery Only

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.219**	0.107***	0.143***	0.149***	0.310	0.123*	0.184***	0.194***
	(2.23)	(3.25)	(5.02)	(5.12)	(1.26)	(1.87)	(3.86)	(4.01)
Post-reform indicator for province-level zone	0.0789	-0.00561	-0.0105	-0.0113	0.0910	-0.000238	0.00138	0.000197
	(1.57)	(-0.25)	(-0.52)	(-0.55)	(1.37)	(-0.01)	(0.05)	(0.01)
Log landarea		0.878***	0.147*	0.0287		0.880***	0.216**	0.0705*
		(18.54)	(1.75)	(0.82)		(11.66)	(2.09)	(1.92)
Log population			0.860***				0.816***	
			(8.85)				(6.10)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	4944	4913	4912	4912	2561	2425	2546	2546
AR2	0.865	0.966	0.973	0.967	0.865	0.962	0.969	0.962

The dependent variable is the logarithm of annual GDP in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita in columns (4) and (8). GDP is measured in current prices. Panel A reports the results for the whole prefecture and Panel B reports the results for the periphery only (the prefecture less the city). All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities in Panel A and 260 cities in Panel B (in 2010) from 25 provinces over the sample period 1988-2010 (unbalanced sample). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table 2.10: Light intensity and electricity consumption

	(1)	(2)	(3)	(4)
Post-reform indicator for any state-level zone	0.0528**	0.0544	0.111**	0.00166
	(2.15)	(1.11)	(2.27)	(0.02)
Post-reform indicator for province-level zone	-0.00854	-0.0338	0.0331	0.0347
	(-0.47)	(-1.22)	(0.97)	(0.81)
Log population	0.0104	0.00175	0.535***	0.212*
	(0.49)	(0.04)	(4.90)	(1.70)
Log landarea			-0.0765	0.0158
			(-1.57)	(0.27)
Dependent variable	log(Light)	log(Light)	log(Electricity)	log(Electricity)
Sample	Full	Inland	Full	Inland
N	4708	2554	5200	2715
AR2	0.836	0.818	0.804	0.758

The dependent variable is the logarithm of light intensity in columns (1)-(2); it is the logarithm of electricity consumption in columns (3)-(4); always at the city level. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 for electricity consumption and 1992-2010 for light intensity. The panel is unbalanced. The regressions in columns (2) and (4) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table 2.11: Controlling for expenditures of the local government

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.145***	0.120***	0.107***	0.0983***	0.225***	0.177***	0.152***	0.134***
	(4.23)	(4.09)	(4.30)	(3.89)	(5.20)	(4.13)	(3.61)	(2.87)
Post-reform indicator for province-level zone	-0.000446	-0.00361	0.00166	0.00534	-0.0125	-0.0245	-0.00772	0.00449
	(-0.02)	(-0.18)	(0.09)	(0.28)	(-0.46)	(-0.92)	(-0.29)	(0.16)
Log gov. spending	0.355***	0.267***	0.206***	0.167***	0.271***	0.234***	0.194***	0.164***
	(7.26)	(7.48)	(6.65)	(5.60)	(6.69)	(6.03)	(5.74)	(5.17)
Log landarea		0.214***	-0.0173	-0.172***		0.193***	-0.0161	-0.168***
		(7.99)	(-0.67)	(-9.14)		(5.69)	(-0.42)	(-5.49)
Log population			0.599***				0.579***	
			(10.81)				(6.42)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	4887	4875	4874	4874	2558	2554	2554	2554
AR2	0.965	0.972	0.976	0.964	0.963	0.969	0.972	0.962

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the city level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

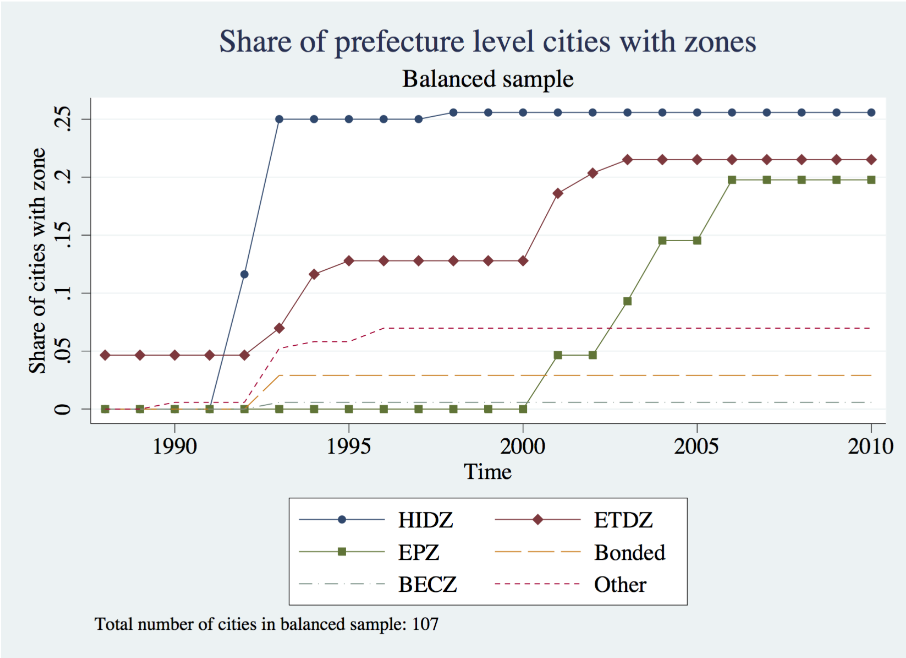
Table 2.12: Baseline specification (census years and population)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for first state-level zone	0.207***	0.162***	0.121***	0.0782**	0.215***	0.153***	0.129**	0.104*
	(4.60)	(4.21)	(3.61)	(2.44)	(3.54)	(2.85)	(2.57)	(1.96)
Post-reform indicator for first province-level zone	0.0473	-0.00655	-0.0210	-0.0361	0.0481	-0.0186	-0.0152	-0.0114
	(1.09)	(-0.20)	(-0.69)	(-1.08)	(0.87)	(-0.45)	(-0.41)	(-0.30)
Log landarea		0.365***	0.0999	-0.178***		0.349***	0.104	-0.163***
		(9.88)	(1.07)	(-3.45)		(8.71)	(1.26)	(-2.74)
Log population			0.488***				0.480***	
			(3.24)				(3.76)	
Census Years	Y	Y	Y	Y	Y	Y	Y	Y
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	708	693	693	693	453	438	438	438
AR2	0.979	0.986	0.987	0.982	0.977	0.986	0.988	0.983

The dependent variable is the logarithm of annual GDP at the prefecture level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the prefecture level in columns (4) and (8). GDP is measured in current prices. All specifications include prefecture fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the prefecture level. The sample includes 276 cities from 25 provinces in 1990, 2000 and 2010, when the population census were conducted (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).The column (3) and (7) include logarithms of population from the census as control variable. The dependent variable in column (4) and (8), logarithms of GDP per capita, is computed with the census population data.

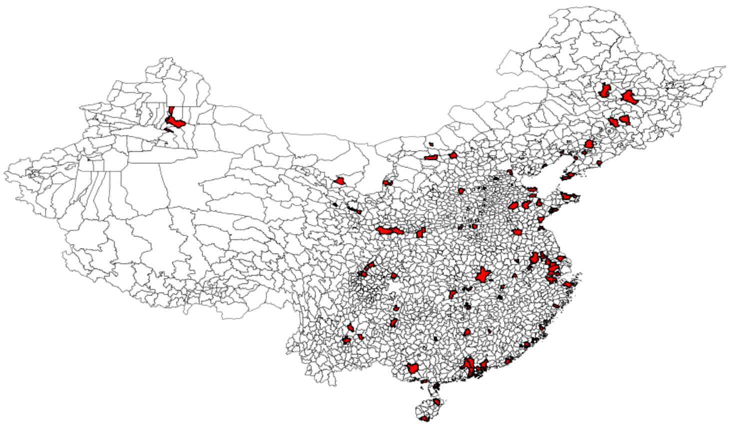
2.9 Figures

Figure 2.1: Share of prefecture level cities with different types of zones



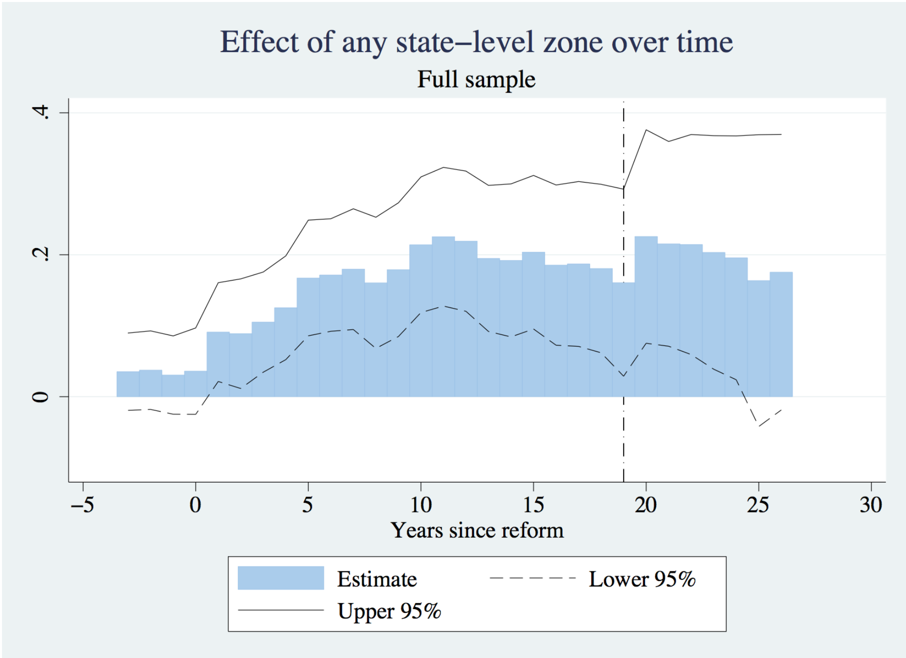
The figure shows the share of cities which have different types of SEZ: Hightech Industrial Development Zones, Economic and Technolocial Development Zones, Export Processing Zones, Bonded Zones, Border Economic Cooperation Zones, and other types. The sample is restricted to 107 cities that are observed in all years between 1988 and 2010.

Figure 2.2: Location of treated cities in 2010



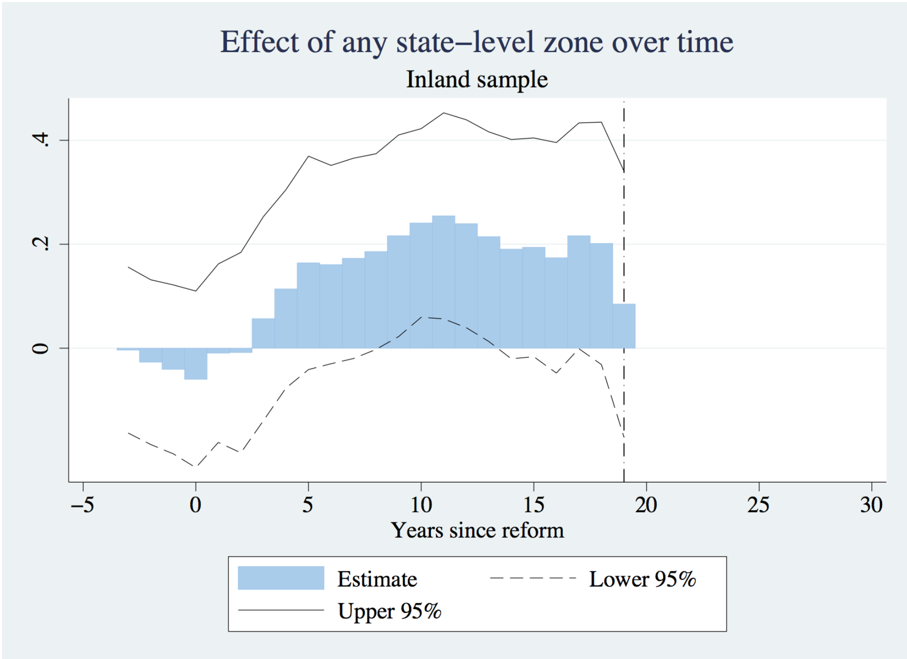
The map shows the boundaries of Chinese prefecture level cities and counties in 2010. The cities in our sample with at least one state-level SEZ in 2010 are marked in red (a city may have more than one zone).

Figure 2.3: Reform effects over time



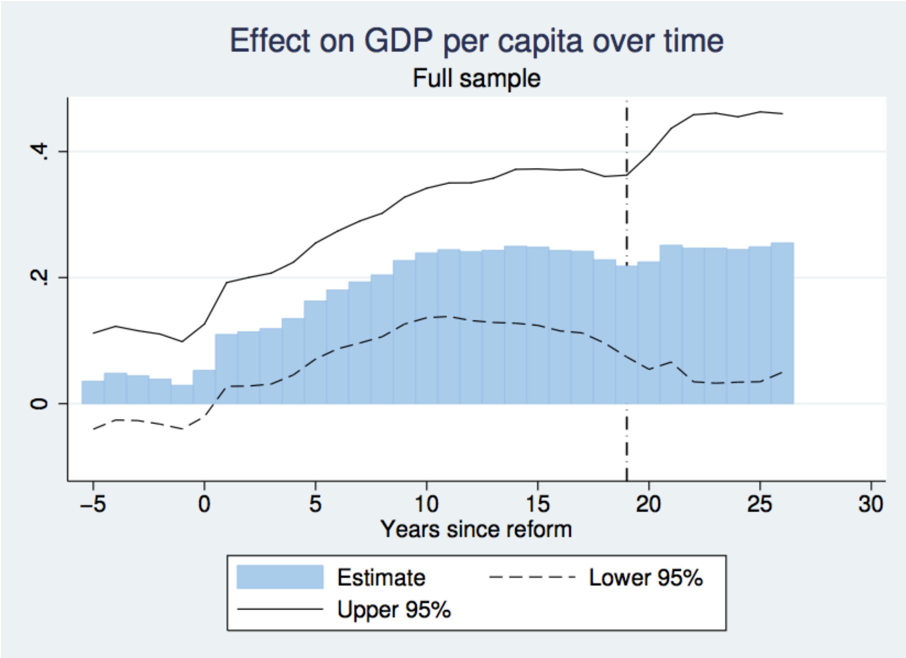
The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after the first zone. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-time fixed effects. Standard errors are clustered by city. The sample includes 276 cities from 25 provinces for the period 1988-2010.

Figure 2.4: Reform effects over time in the inland sample



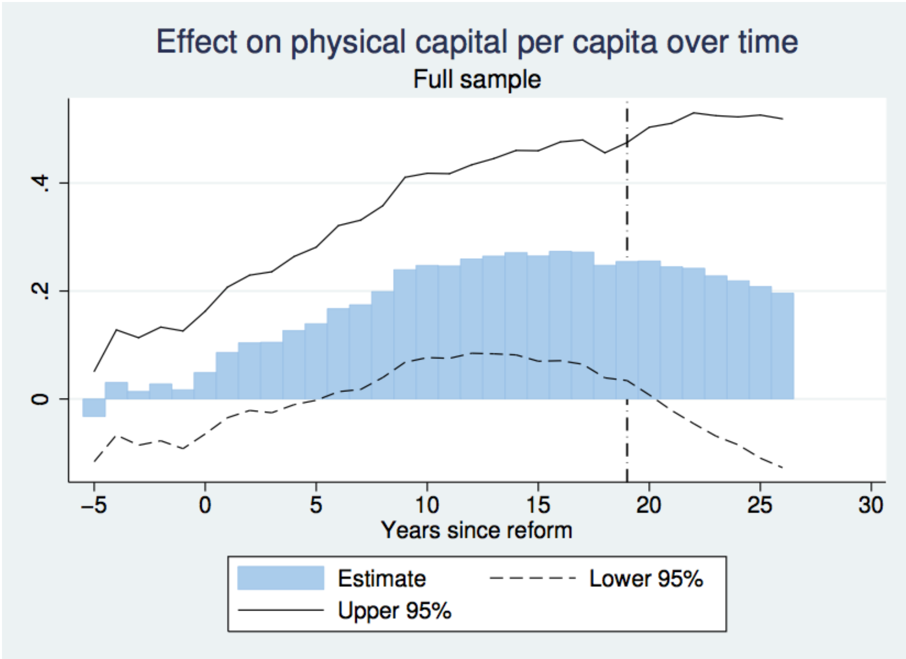
The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after the first zone. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-time fixed effects. Standard errors are clustered by city. The sample includes 158 cities from 18 inland provinces (as defined in the appendix) for the period 1988-2010.

Figure 2.5: Effects on GDP per capita over time



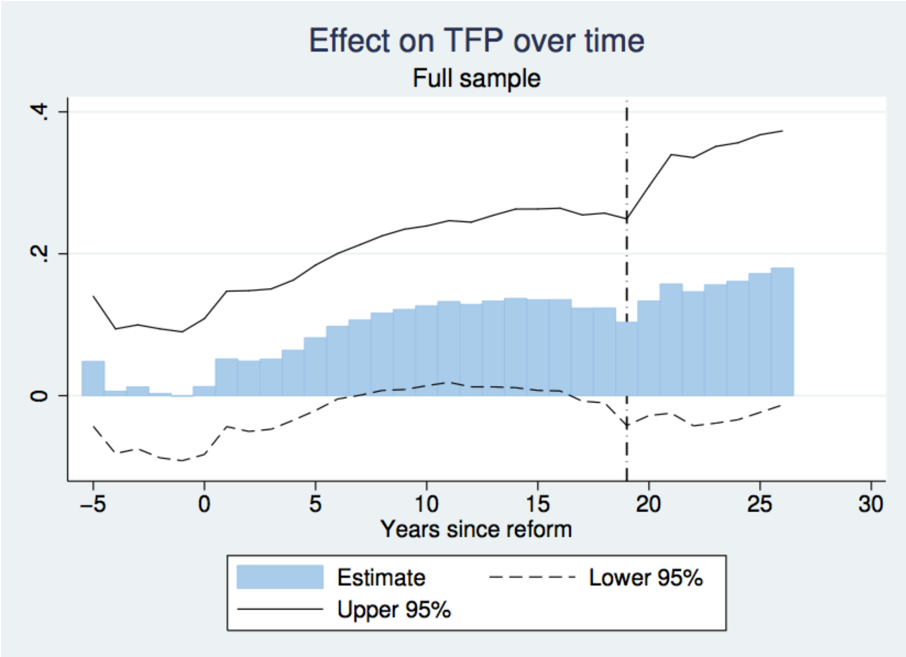
The bars show the coefficients of a regression of the logarithm of GDP per capita on indicators for years before and after the first SEZ was established. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression uses data at the prefecture level and also controls for an indicator for province-level zones, land area of the prefecture, prefecture fixed effects, and province-time fixed effects. Standard errors are clustered by prefecture. The sample includes 276 cities from 25 provinces for the period 1988-2010.

Figure 2.6: Effects on physical capital per capita over time



The bars show the coefficients of a regression of the logarithm of physical capital per capita on indicators for years before and after the first SEZ was established. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression uses data at the prefecture level and also controls for an indicator for province-level zones, land area of the prefecture, prefecture fixed effects, and province-time fixed effects. Standard errors are clustered by prefecture. The sample includes 276 cities from 25 provinces for the period 1988-2010.

Figure 2.7: Effects on TFP over time



The bars show the coefficients of a regression of the logarithm of TFP on indicators for years before and after the first SEZ was established. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression uses data at the prefecture level and also controls for an indicator for province-level zones, land area of the prefecture, prefecture fixed effects, and province-time fixed effects. Standard errors are clustered by prefecture. The sample includes 276 cities from 25 provinces for the period 1988-2010.

3 Divide and Rule: An Origin of Polarization and Ethnic Conflict

Joint with Yikai Wang

3.1 Introduction

Violent conflict causes enormous costs for people, and yet we often observe wide support in the population for political elites that initiate conflicts. A recent literature has argued theoretically and empirically that ethnic polarization is an important determinant of the incidence of conflict (see for example Esteban, Mayoral, and Ray, 2012). Many recent civil wars were indeed fought along ethnic lines. Conflicts between Hutu and Tutsi in Rwanda have led to around 800,000 deaths from genocide and triggered further violence in the form of counter-attacks and civil wars in the larger region (Prunier, 2009).[1] For the vast majority of people the consequences of this ethnic violence were catastrophic.

How can ethnic groups be so highly polarized that deadly violence erupts on a large scale? Predetermined differences can hardly be an explanation, as the same groups have lived in peace for long periods of time. For example, there is no evidence of political violence between Hutu and Tutsi before 1959 (Gourevitch, 1998) and the ethnic labels did not even have a political meaning until the mid 19th century (Pottier, 2002). In contrast, there are numerous examples in Rwanda and elsewhere showing that ethnic violence was a *strategic choice* of a political elite. Fearon and Laitin (2000: 846) emphasize this in their review of conflict studies:

> "If there is a dominant or most common narrative in the texts under review, it is that large-scale ethnic violence is provoked by elites seeking to gain, maintain, or increase their hold on political power."

By initiating conflict along ethnic lines, elites can deepen ethnic divisions and thus increase polarization (Horowitz, 2000). The polarization in society strengthens the position of

[1] Ethnicity is also a key component of conflicts in Yugoslavia. Section 3.3 provides a more detailed description of these cases.

the elite and allows it to exploit power. This strategy is well known as "divide-and-rule"(Posner, Spier, and Vermeule, 2010).[2]

We propose a model of divide-and-rule where the ethnic polarization between groups is endogenous. Polarization is modeled as a lack of trust between ethnic groups. High levels of trust threaten the autocratic elite because it may be overthrown if trust is high and the common interest among the ethnic groups in society becomes large. A key question for such a divide-and-rule argument is how an elite can induce people to polarize. Fearon and Laitin (2000: 853) describe this challenge as follows:

> "The puzzle for such theoretical arguments is to explain how elites can convince their followers to adopt false beliefs and take actions that the followers would not want to take if they understood what the leaders were up to."

Our contribution is to provide a micro-foundation for how elites can polarize society when people are rational. This is achieved by embedding a model of trade and trust (Rohner, Thoenig, and Zilibotti, 2013a) into a political economy framework that allows for war and revolution (Besley and Persson, 2011).

The model society has two ethnic groups of equal size, one of which initially being the incumbent group. Within each group, there is a small political elite that derives rents from being in power. We start from a situation of autocracy where the elite of the incumbent group sets policies. The incumbent elite faces a threat from the other group (transition of power) and from the people of its own group (revolution). A revolution leads to a regime switch to democracy where people of both groups trade with each other without being expropriated by an elite. The threat of revolution therefore depends on the expected gains from trade.

Similar to Rohner, Thoenig, and Zilibotti (2013a), we model the expected outcome of trade as a function of trust between trade partners. More specifically, the outcome of trade is stochastic and the likelihood of a good trade outcome depends on how mutually beneficial trade is (e.g. the complementarity between the trade partners), which is unknown. Agents hold a prior belief about how beneficial trade is. A belief that trade is beneficial implies a high level of trust. Trust can increase through Bayesian updating of this belief after good trade outcomes occur. However, trade can only take place during peaceful times such that trust cannot emerge while there is war. The ruling elite can therefore prevent trust from emerging by starting a war. This enables the elite to limit the threat of revolution that originates in the common interest of people when trust is high.

[2]Posner, Spier, and Vermeule (2010) discuss divide-and-rule strategies from a theoretical perspective. See also Acemoglu, Robinson, and Verdier (2004).

The precise tradeoffs faced by the people and by the elite are as follows. A currently ruling elite taxes people in both groups but redistributes part of the revenues as transfers to the people of its own group. When trust is very low and therefore expected gains from trade small, then transfers are relatively more important for the people of the incumbent group than the gains from trade. They therefore prefer their own elite to stay in power. The probability that the currently ruling group stays in power is higher when it fights a war against the other group than when it is in peace. Elite and people of the incumbent group therefore both support war when trust is very low. When trust increases somewhat, the people start to prefer peace because they want to reap the gains from trade with the other group. But the elite still prefers war over peace because it is afraid of losing power to the other group. The people are less concerned about such a transition of power because they know that they will still have part of the trade surplus even if the other group takes over. This setting therefore generates that the elite stays at war for longer than is optimal for the people, because the elite has more at stake from being in power.

At intermediate levels of trust, both elite and people of the incumbent group support peace and trade with the other group. Both also prefer to maintain the autocracy because it allows them to exploit the other group. The interest of elite and people of the incumbent group are therefore aligned again for these intermediate levels of trust. But when trust increases further to a high level, the interests start to diverge once more: income from trade surplus becomes so high that it is more important for the people of the incumbent group than the transfers through their elite. The people may therefore start a revolution and establish a peaceful democracy with the other group in order to reap the full benefits from trade without being taxed by an elite. The elite on the other hand loses all its rents when there is a revolution. At high levels of trust, we therefore again get the result that the elite starts a war in order to lower the chances of losing power, while people would prefer to trade in peace.

In summary, an autocratic elite that knows that trust is relatively high has to decide if it should allow for peace or start a war. It faces the following tradeoff: (1) During peace, people can trade across groups and this may (depending on whether trade outcomes are good) generate trade surpluses that the elite can tax. However, good trade outcomes also imply that people update their beliefs such that trust can emerge. The expectation of high gains from trade (based on high trust) increases the threat of revolution, since people may become willing to incur the cost of revolution in order to not have the trade surplus taxed by the elite. (2) If the elite starts a war, then there is no trade and the elite therefore cannot tax the trade surplus. But it also prevents trust from emerging between the two ethnic groups, which limits the risk of a revolution. A key implication of this setup is that the elite can apply a divide-and-rule strategy: when the threat of revolution is high, it starts a conflict between the groups, which harms trust, polarizes society, and limits the common interest of people. This strategy is against the interest of both groups of people in society, since they may be better off under a democracy where they trade and are not exploited by an elite.

The rest of the paper is organized as follows. Section 3.2 reviews the related literature, including empirical studies on conflict and ethnic polarization as well as theoretical work on the divide-and-rule strategy. In section 3.3, we discuss the anecdotal evidence on the divide-and-rule strategy, in particular the cases of Rwanda and Yugoslavia. Section 3.4 presents a simple benchmark model to illustrate how the tradeoff between peace and war depends on trust. In section 3.5, the benchmark model is extended to a dynamic setting to study how trust evolves over time and how it can be manipulated by the elite. Finally, we conclude in section 3.6.

3.2 Related Literature

This paper is related to several strands in the existing literature. First, we relate to a large literature on civil conflict (Blattman and Miguel, 2010, provide a survey). Fearon and Laitin (2003) estimate that there were about 127 major civil wars between 1945 and 1999 with more than 16 million fatalities overall. Our analysis is particularly related to the strand in the civil war literature focusing on conflict between ethnic groups. Esteban and Ray (2011), Esteban, Mayoral, and Ray (2012), and Rohner (2011) show that the polarization of societies along ethnic lines is associated with high degrees of conflict. Esteban and Ray (2008) argue that coalitions along ethnic lines are more likely to emerge than along classes. Caselli and Coleman (2013) point out that certain ethnic characteristics that are easily observable (such as skin color) allow to distinguish between winners and losers of a conflict and therefore make starting a conflict along these lines more profitable. Besley and Persson (2011) provide a framework where repression and civil war can depend on polarization between groups. We contribute to this literature by endogenizing ethnic polarization. In our framework, a ruling elite can strategically affect polarization between people in order to sustain its own power. Such patterns of "divide-and-rule" have been described also outside of the economic literature.[3] Related papers have argued that a political elite can expropriate its supporting group because of their fear that otherwise

[3]See for example the review of case studies by Fearon and Laitin (2000). Similarly, Horowitz (2000) writes "By appealing to electorates in ethnic terms, by making ethnic demands on government, and by bolstering the influence of ethnically chauvinist elements within each group, parties that begin by merely mirroring ethnic divisions help to deepen and extend them. Hence the oft-heard remark in such states that the politicians have created ethnic conflict."

an even less favorable elite would take over (De Figueiredo and Weingast, 1997; Padro i Miquel, 2007)

The findings on the salience of ethnic conflict are complemented by a set of theoretical papers on divide-and-rule strategies. Posner, Spier, and Vermeule (2010) analyze divide-and-rule strategies in two simple game theoretic models, the Prisoner's Dilemma and the Stag Hunt Game. They consider how an outsider (the elite) that is affected by the cooperation of the agents can influence outcomes.[4] They state that two conditions are important for such strategies: "(1) A unitary actor bargains with or competes against a set of multiple actors. (2) The unitary actor follows an intentional strategy of exploiting problems of coordination or collective action among the multiple actors." They consider different ways to apply a divide-and-rule strategy: destroying communication channels, payment of bribes, imposition of penalties, generating distrust, limiting interaction, and mixing agents with heterogeneous interests. Our model is best described by the category "generating distrust". However, Posner, Spier, and Vermeule (2010) implement this by the elite being able to directly manipulate agents beliefs about the other agents' private payoffs. In contrast, we provide a setting where the elite cannot directly manipulate beliefs, but it can limit the learning process between agents by starting conflict. In this sense our setting also relates to the category "limiting interaction", although their use of this strategy refers to limiting the time horizon of repeated interactions.

Acemoglu, Robinson, and Verdier (2004) consider a divide-and-rule strategy that falls into the category described by Posner, Spier, and Vermeule (2010) as "payment of bribes". In Acemoglu, Robinson, and Verdier (2004), elites can exploit people because they can prevent them from cooperating in a revolution. The kleptocratic elite achieve this by bribing one of two groups in society in order to induce them to reject offers by the other group to cooperate in a revolution. They show that such kleptocratic regimes are more likely to arise if the regime faces fractionalized opponents instead of large players that can solve the coordination problem internally and thus put a constraint on the behaviour of the ruler.

We model polarization as a lack of common interest, which in turn depends on trust between trade partners. This is based on Rohner, Thoenig, and Zilibotti (2013a) where trust and cooperation is shaped by Bayesian updating during interactions with the trade partner. Rohner, Thoenig, and Zilibotti (2013a) show that even accidental conflicts can be persistent and generate cycles of recurring conflict due to the destruction of trust. Such cycles are also a feature of Acemoglu, Ticchi, and Vindigni (2010), although without the

[4]Posner, Spier, and Vermeule (2010) use the term "divide-and-conquer", which is equivalent to "divide-and-rule". The Oxford Dictionary (2014) defines both terms as "[t]he policy of maintaining control over one's subordinates or opponents by encouraging dissent between them, thereby preventing them from uniting in opposition."

link to trade. Rohner, Thoenig, and Zilibotti (2013b) provide empirical evidence on the effect of conflict on trust in Uganda. A related literature has analyzed social learning (for example Banerjee, 1992; Acemoglu and Wolitzky, 2014). Our contribution to this literature is to show that a conflict can be started strategically by the currently ruling elite in order to affect people's beliefs and to sustain its own power.

The channel through which in this framework polarisation can be manipulated by a political elite is trade. We therefore relate to the literature on the relationship between conflict and trade – without the link to trust. The "liberal peace" argument postulates that increased economic interdependence through trade between countries reduces the likelihood of conflict. However, recent contributions find that this relationship is more complex. Barbieri (1996) finds that strong economic interdependence is positively associated with militarised conflict. Martin, Mayer, and Thoenig (2008) show theoretically and empirically that increases in multilateral trade increases the risk of conflict, especially between neighboring states.[5] In our framework, an increase in trade may fail to prevent conflict for a different reason: a forward looking autocratic elite fears that high levels of economic interaction will augment the common interest of people because this increases the threat that the elite may be overthrown by the people.

3.3 Evidence on Divide-And-Rule Strategies

Our model provides a micro-foundation for why and how an elite strategically polarizes society in order to sustain its own power. Such patterns have frequently been described in the literature (Fearon and Laitin, 2000). The evidence suggests that provoking conflict is a way of polarizing society. We discuss two cases below that illustrate the role of violence for polarization. These examples will show that ethnic conflict was initiated by elites with the purpose of dividing society, which allowed them to strengthen their role as the ruling elite. We first discuss the case of Rwanda in detail and then show that similar developments have occurred in Yugoslavia.

3.3.1 Rwanda

The history of Rwanda and of its neighbouring countries contains several episodes of large-scale ethnic violence. The conflict between Tutsi and Hutu is often associated with extreme hatred and violence between deeply divided ethnic groups.[6] But the ethnic

[5] The liberal peace argument has recently also been challenged by other authors, for example Goldsmith (2013) or Gowa and Hicks (2014).

[6] Hutu (Bantu) are the majority group in Rwanda with 84% of the population. Tutsi (Hamitic) account for 15% and Twa (Pygmy) for 1% (CIA World Factbook, 2014).

cleavages were not just due to pre-existing differences between people. Neither is there evidence that ethnic groups in Rwanda have always been in violent conflict with each other. On the contrary, it seems that there has been no systematic political violence between Hutu and Tutsi before 1959 (Gourevitch, 1998).

The history of Rwanda is an example of how ethnicity is to some extent "constructed" by elites for their own benefit.[7] We show below that the motivation for creating ethnic tensions often was the elite's aim to sustain its power in response to political or socio-economic changes. Contrary to the belief that predetermined ethnic differences triggered conflict, it seems that the conflict in the 1990s "had its origin in modern struggles for power and wealth" (Pottier, 2002).

Evidence on how the terms Hutu and Tutsi were initially used prior to colonisation is scant. But it appears that before 1860 there was substantial social mobility and "ethnicity was not a principal organising factor" (Pottier, 2002). From the mid 19th century on, it is known that the Tutsi king Rwabugiri started to polarise the Rwandan people with discriminating rules concerning the ownership of cattle (Newbury, 1988). Families rich in cattle were regarded as Tutsi while poorer families were labeled Hutu. Therefore, "[...] wealth, not race, was the basis of the ethnic distinction between Hutu and Tutsi" (Pottier, 2002: 14).

In her study of the impact on the region of Kinyaga, Newbury (1978) states that "social stratification" was among the most important transformation due to the new rule. The king established chiefs from outside of the community in order to collect taxes and these chiefs were typically Tutsi. This led to a strong association of the sharpened ethnic distinction with social status and a notion of inferiority of the Hutus. However, it did not yet lead to systematic violence. The use of external chiefs also broke up the ties within clans and led to struggles among the groups to be favoured by the rulers. This weakened the people and strengthened the rule of the elite (Newbury, 1978). Therefore, while ethnicity initially played a minor role in Rwanda, it became an increasingly important factor due to policies that polarised society.

With colonization, ethnic identity gained further relevance. The European colonizers used the Tutsi administration in order to control the country and even helped it in expanding its region of influence. The Hutus were under "dual colonialism" by the Tutsi administration and Belgian colonizers (Newbury, 1998).[8] Belgian colonizers actively divided society further. In 1933-34, they introduced identity cards that labeled individuals as either "Hutu", "Tutsi", or "Twa" (Gourevitch, 1998). This labelling drastically reduced

[7] See Fearon and Laitin (2000) for a comprehensive discussion of the "construction" of ethnic differences and the implications for violent conflict.

[8] The Belgium support of the Tutsi elite ended only shortly before independence when it started supporting the Hutu majority (Pottier, 2002).

the mobility between Hutu and Tutsi, which previously was relatively high. Gourevitch (1998: 57) explains how ethnicity gained importance with the identity cards:

> "The identity cards made it virtually impossible for Hutus to become Tutsis, and permitted the Belgians to perfect the administration of an apartheid system rooted in the myth of Tutsi superiority. [...] Whatever Hutu and Tutsi identity may have stood for in the precolonial state no longer mattered; the Belgians had made "ethnicity" the defining feature of Rwandan existence."

Rwanda therefore had several episodes that show how ethnic differences were constructed by an elite for their own benefit. This polarization of Rwanda through dividing people along ethnic lines had a persistent effect on the relationship between Hutu and Tutsi. It repeatedly led to large scale conflict over several decades in Rwanda and in its neighbouring countries. The ethnic distinction that was initially strengthened by the king and then by colonial powers was since shortly before independence repeatedly used by the elites of both Hutu and Tutsi in order to gain political power.

According to Prunier (1995), the ethnic identity was a key aspect in the mobilization of Hutu peasants in the genocide that started in 1994. One channel through which elites could affect polarization was trust. Prior to the start of the genocide, Hutu extremists purposely fostered conflict in order to harm the interaction between moderate Hutu and Tutsi and to reduce trust. Their success with this strategy of limiting the relevance of moderate Hutus strengthened their position within the Hutu group. This allowed them to mobilize the masses for the genocide. Fearon and Laitin (2000: 865) describe this episode as follows:

> "In 1992, two years before the genocide, moderate Hutus gained some control over the tense situation and negotiated a cease-fire with the Rwandan Patriotic Front (RPF, a guerrilla movement that despite seeking a multiethnic constituency, represented Tutsi interests) at Arusha. But Hutu extremists led by the president's wife, Agathe Habyarimana, began taking to the streets against the ensuing peace process. She and her three brothers helped form the "Zero Network" death squads, the institutional precursors of the genocide. After a formal power-sharing deal was signed in January 1993, and the day the International Commission on Human Rights mission left, the extremist Hutus sent their squads to the northwest region where they were strong, and three hundred Tutsis were killed in six days of violence. The in-exile Tutsi-led army then broke the cease-fire and marched across the Ugandan border toward the Rwanda capital, with many of the soldiers defying their own moderate leadership. These wildcats engaged in counterviolence, scaring many Hutus who

> escaped to Zaire. [...] Unable to assign blame for the failure of the cease-fire with certainty, Hutu moderates increased their estimate that the RPF could not be trusted in political negotiations, exactly what the extremists had sought in their violent attacks."

The legacy of ethnic conflict and polarisation went much beyond the genocide. After Tutsi groups gained power and ended the genocide of Tutsis by Hutus, there were repeated counter-killings undertaken by Tutsi extremists. The large refugee flows destabilised the entire region and contributed to the two Congo Wars (Prunier, 2009). These wars drew several countries of the region into violence and were the deadliest since the Second World War. A key figure in the first Congo War was Mobutu, president of the Democratic Republic of Congo. He also followed the strategy of "ethnicizing the political situation" (Prunier, 2009: 78) in order to sustain his own power. He purposely destabilised the region by manipulating refugees and constantly changing who is favoured by his regime. Acemoglu, Robinson, and Verdier (2004) describe him as a clear example of a kleptocratic leader that applied a divide-and-rule strategy to sustain his own power.

3.3.2 Yugoslavia

In the late 1980s, Yugoslavia was a relatively open country that allowed for free travel of people and movement of goods. As Woodward (1995) points out, Yugoslavia was in a good position to make a successful transition to a free market economy and it was moving towards an integration with the West.[9] This trend changed abruptly after 1989 and over the following two years Yugoslavia experienced wars, disintegration, and the creation of new states. War in Croatia led to 20,000 deaths and more than 200,000 refugees. In Bosnia-Herzegovina, it generated 2 million refugees and 70,000 fatalities.

Although intrinsic ethnic differences are often used as an explanation for the eruption of violence in the region, the case of Yugoslavia actually provides yet another example of how political elites *construct* ethnicity in order to divide people and sustain their own power. Referring to the Balkan conflict, Fearon and Laitin (2000: 867) state that violence was used strategically:

> "[...to] foment outrage among their own moderates, ethnic leaders will provoke interethnic violence."

An important episode discussed by Woodward (1995: 90) describes how Slobodan Milŏsević polarized politics:

[9]Unless otherwise noted, the historical exposition below is based on Woodward (1995).

> "The Serbian shift was part of a factional struggle within the Serbian party, which culminated at the eighth party plenum (September 23-24 [1987]), when Slobodan Milŏsević made a successful move to oust his former patron and friend Ivan Stambolić as president of Serbia and to engineer a coup against its Belgrade party organization, Serbia's most powerful (and liberal). Milŏsević accused Stambolić's crowd of being too lenient on Albanians in Kosovo and of failing to protect Serbian territorial integrity and Serbs and Montenegrins from forced expulsion."

One interpretation of this description is that Slobodan Milŏsević strategically sought to polarize in order to gain power within his own group. By provoking fear of other groups, he could convince his own people that cooperation with them was not an option. That Milŏsević was acting strategically – and not just motivated by his own extremist ideas – is confirmed by the former US ambassador to Yugoslavia from 1989 to 1992, Warren Zimmermann. In his review of this period, he writes (Zimmermann, 1995: 5):

> "Milŏsević is an opportunist, not an ideologue, a man driven by power rather than nationalism. He has made a Faustian pact with nationalism as a way to gain and hold power."

Zimmermann (1995: 12) also makes clear that the nationalism that emerged in Yugoslavia during this period was the product of elite's manipulation by way of triggering ethnic violence:

> "The breakup of Yugoslavia is a classic example of nationalism from the top down – a manipulated nationalism in a region where peace has historically prevailed more than war and in which a quarter of the population were in mixed marriages. The manipulators condoned and even provoked local ethnic violence in order to engender animosities that could then be magnified by the press, leading to further violence."

The descriptions above show that elites can strategically start ethnic conflict in order to affect trust and to divide societies. They may apply such a policy of divide-and-rule to strengthen their power. The incentives to do so depend on the rents from being in power and the gains from peaceful trade. The model in the next section allows us to analyse this tradeoff.

3.4 The Benchmark Model

In this section, we discuss a static model as a benchmark. This allows us to discuss the basic tradeoffs of the elite between war and peace and the people's decision to revolt.

Section 3.5 will then extend the model to a dynamic setting to discuss the evolution of trust over time and how it can be affected by the elite.

3.4.1 Environment

The model is based on Besley and Persson (2011) and consists of two ethnic groups, A and B. One group is the incumbent group, while the other is the opponent group. In this section, we assume that group A initially is the incumbent group. Within each group, there are two types of agents: an elite and the people. The elites do not produce. People in each group can produce at home and also benefit from trade with the other group. The incomes of people in the incumbent and the opponent group through home production are y_I and y_O, respectively, and the income from trade is y_T, which for simplicity is assumed to be the same for both groups. In the following, we always denote the people in the incumbent and the opponent group as I and O, respectively. Moreover, we denote the elite in the incumbent group as E.[10]

There are two types of political systems: autocracy and democracy. In autocracy, the elite of the incumbent group controls the government and makes the following decisions. First, it decides whether to be at war or peace with the opponent group. Second, it sets economic policies: taxes and transfers. The role of the people of the incumbent group is to trade with the other group (only under peace) and to choose whether to revolt against the ruling elite. If a revolution occurs, the regime switches to democracy. In democracy, the elite plays no role anymore, people from both groups together run the government, and the equilibrium is laissez-faire. In other words, we assume away tyranny of the majority in democracy. This means that we avoid the case where one group decides policies and exploits the other group.[11] We use superscript W, P, and R to indicate the possible states of the world, i.e. war, peace and revolution, respectively.

The outcome of trade can be "good", in which case it yields the surplus y_H for both groups, or "bad", in which case the surplus is $y_L < y_H$. The probability of getting the good outcome depends on the type of relation between the two ethnic groups. If the relation is of type "beneficial", the outcome is good with probability q_H and bad with probability $1-q_H$; if it is "harmful", the outcome is bad with probability q_L and good with probability $1-q_L$.[12] Naturally, we assume $q_H > 1-q_L$, that is to say, if the relation is beneficial, the

[10] The elite of the opponent group plays no role in the model, as we will see later, which is why we refer to the incumbent elite simply as the elite and use the index E.

[11] Note that we assume that the two groups are of equal size. However, even in this case a majority decision could favour one group.

[12] Although in our model the expected gains from trade cannot be negative even for the "harmful" relation, this could well be the case in reality. We therefore use the term "harmful", although "not beneficial" would also be an accurate description.

probability of a good trade outcome is higher than under a "harmful" relation. The agents don't know the type of relation for sure, but hold a common belief about the probability of the relation being beneficial, denoted by p.

We interpret this framework as follows. The type of the relation between two ethnic groups, or equivalently, the likelihood of getting good outcomes from trade, depends on the characteristics of the two groups. For example, if two groups have complementary skills, it is more likely that trade and cooperation between them lead to good outcomes. If the two groups can't communicate well during the trade, for example due to conflicting cultures, then there may be very costly frictions in trade that lead to a low trade surplus. Moreover, we interpret p as trust: the higher is trust in the relation (believing that with high probability the relation is beneficial), the higher is the expected trade surplus. It also implies a larger common interest between the two groups. We therefore view trust as the opposite of ethnic polarization, since the latter emphasizes the conflicting interests across groups.

The timing is shown in Figure 3.1 and it is described in detail below:

1. At the beginning of the period, the political regime is autocracy. The level of trust p is given.

2. I people decide to revolt or not.

   (a) If revolution happens, I people pay the (exogenous) cost f^R and the political system switches to democracy. The elite pays the cost f_E^R and disappears. Then, both groups of people live in the laissez-faire equilibrium and the game ends.

   (b) If there is no revolution, then autocracy survives. The elite stays in government and the game moves to step 3.

3. With a continuing autocracy, the elite decides whether to wage war against O or to retain peace.

   (a) If war occurs, I people pay the cost f^W. There is no trade and the game goes to step 5.

   (b) If peace is chosen, I people can trade with O people and the game goes to step 4.

4. Trade: If trade occurs – either in democracy or in peaceful autocracy – then its outcome can either be good (y_H) or bad (y_L) as described in the text above.

5. Political turnover: In autocracy, with probability π^s, the existing incumbent group remains as the incumbent group, and with probability $1 - \pi^s$, the other group becomes the new incumbent. The superscript $s \in \{W, P\}$ denotes the state of the world: war or peace. Turnover is less likely when there is war, such that $\pi^P < \pi^W$. In democracy, as both groups of people live in the laissez-faire equilibrium, the distinction of incumbent and opponent group no longer exists.

6. Tax and transfer: In autocracy, the elite from the incumbent group chooses the tax rate on the total income of people, including production and trade surplus. Moreover the elite decides transfer to the people. In democracy, the laissez-faire equilibrium implies that there are no taxes and transfers.

7. Finally, trade outcome realizes and incomes, taxes, and transfers are allocated.

Following Beasley and Persson (2011), we assume that the maximal tax rate is exogenously determined by the state capacity, denoted by τ. The minimal transfer to I people is a θ fraction of total taxes, which is also exogenously determined by checks and balances. Transfers to O people are 0. To understand the state capacity, we can think of the following case: tax payers can hide each unit of income at cost τ. The more capable the state is, the higher costs tax payers have to pay to hide their income. The state, in order to maximize the tax income, prefers to set the tax rate as high as τ, but it can not set it higher, as the Laffer curve goes down towards 0 for tax rates higher than τ. Moreover, the elite sets transfers as low as possible. Therefore, in autocracy, the transfers to I people are a θ fraction of total tax and to O people they are 0. Note that transfers happen after the revolution decision by the people. This implies that a promise by the elite to transfer more than the minimum amount given by checks and balances is not credible. Therefore, a promise of transfers cannot be used by the elite to prevent revolution.

3.4.2 Incomes

The equilibrium concept is sub-game perfect Nash equilibrium. We solve the model by backward induction. First of all, we calculate the payoffs of the game, i.e. the incomes of the agents – the elite and the incumbent people – in all the states of the world, i.e. in war, peace, and revolution.

3.4.2.1 I People

The expected trade surplus given belief p is the following:

$$\begin{aligned} E\left[y_T\right] &= p\left(q_H y_H + \left(1-q_H\right) y_L\right) + (1-p)\left(q_L y_L + \left(1-q_L\right) y_H\right) \\ &= p\left(q_H + q_L - 1\right)\left(y_H - y_L\right) + \left(q_L y_L + \left(1-q_L\right) y_H\right). \end{aligned}$$

Recall that $q_H > 1 - q_L$. We know that y_P is positively correlated with p, namely, the higher trust, the higher is the expected trade surplus. To simplify the expression, we set

$$\begin{aligned} y_H &= \frac{q_L}{q_H + q_L - 1}, \\ y_L &= \frac{q_L - 1}{q_H + q_L - 1}, \end{aligned}$$

which leads to

$$E\left[y_T\right] = p.$$

The key relationship between the trade surplus and the belief of the other group is preserved, so this normalization is without loss of generality and does not change the results of this model.

The final expected income of I people includes production, trade surplus, and transfers minus taxes. I people get positive transfers if group I stays the incumbent group. If a political turnover occurs, I people become the opponent group and get 0 in transfers. This implies the following incomes of the I people in each state of the world:

- Peace: $y_I^P = (1-\tau)(y_I + p) + \pi^P \theta\tau(y_I + y_O + 2p)$.
- War: $y_I^W = (1-\tau)y_I + \pi^W \theta\tau(y_I + y_O - f^W)$.
- Revolution: $y_I^R = y_I + p - f^R$.

We assume that $\pi^W > \pi^P$, implying that for group I, there is a tradeoff between peace and war: in peace, there is extra income from trade, while in war, the probability of staying as the incumbent group is higher. Peace dominates war for I people if and only if trust, or equivalently, the expected gain from trade, p, is large enough. In this case, $y_I^P \geq y_I^W$, which is equivalent to the following:

$$\begin{aligned} (1-\tau)(y_I + p) + \pi^P\theta\tau(y_I + y_O + 2p) &\geq (1-\tau)y_I + \pi^W\theta\tau(y_I + y_O - f^W) \iff \\ p &\geq \frac{\left(\pi^W - \pi^P\right)\theta\tau(y_I + y_O) - \pi^W\theta\tau f^W}{1 - \tau + 2\pi^P\theta\tau} \\ &\doteq p^W. \end{aligned}$$

In other words, if $p < p^W$, I people strictly prefer to go to war instead of peace. When do I people prefer revolution to peace? Under the condition that $\theta < \frac{1}{2\pi^P}$, we can derive the condition as follows:

$$\begin{aligned} y_I^R &\geq y_I^P \iff \\ y_I + p - f^R &\geq (1-\tau)(y_I + p) + \pi^P \theta \tau (y_I + y_O + 2p) \iff \\ p &\geq \frac{\pi^P \theta \tau y_O - \left(1 - \pi^P \theta\right) \tau y_I + f^R}{\tau(1 - 2\pi^P \theta)} \\ &\doteq p^R. \end{aligned}$$

The condition that $\theta < \frac{1}{2\pi^P}$ implies that the transfer to I people can not be too large. If it is violated, I people expect to get more transfers than what they pay in taxes. Their income would then increase by more than 1 unit when trust and the trade surplus for them increase by 1 unit. This would lead to the case that I and O people cooperate to start the revolution only when trust between them is very low. This case is unlikely to happen in the real world and we therefore rule it out. We maintain this as an assumption throughout the paper:

Assumption 1. $\theta < \frac{1}{2\pi^P}$.

3.4.2.2 Elite

If it can maintain its power, then the final income of the elite consists of taxes minus transfers. If there is a revolution, then it incurs a high cost because it is thrown out of the government. The payoffs for each state of the world are therefore as follows:

- Peace: $y_E^P = \pi^P(1-\theta)\tau(y_I + y_O + 2p)$.
- War: $y_E^W = \pi^W(1-\theta)\tau(y_I + y_O - f^W)$.
- Revolution: $y_E^R = -f_E^R$.

If there is no revolution, then the elite prefers peace to war when p is large enough:

$$\begin{aligned} y_E^P &\geq y_E^W \iff \\ \pi^P(1-\theta)\tau(y_I + y_O + 2p) &\geq \pi^W(1-\theta)\tau(y_I + y_O - f^W) \iff \\ p &\geq \frac{\left(\pi^W - \pi^P\right)\tau(y_I + y_O) - \pi^W \tau f^W}{2\pi^P \tau} \\ &\doteq p_E^W. \end{aligned}$$

It can be verified that $p_E^W > p^W$ by observing the following:

$$\begin{aligned} p^W &= \frac{\left(\pi^W - \pi^P\right)\theta\tau(y_I + y_O) - \pi^W\theta\tau f^W}{1 - \tau + 2\pi^P\theta\tau} \\ &= \frac{\left(\pi^W - \pi^P\right)\tau(y_I + y_O) - \pi^W\tau f^W}{\frac{1-\tau}{\theta} + 2\pi^P\tau} \\ &< \frac{\left(\pi^W - \pi^P\right)\tau(y_I + y_O) - \pi^W\tau f^W}{2\pi^P\tau} \\ &\doteq p_E^W. \end{aligned}$$

This implies that the elite, compared to the people, is more willing to go to war when the trust is relatively low. The reason is that if the political turnover occurs, the elite loses more compared to I people, who can still get the after-tax income even under the rule of the other group. This difference between the elite and the people in the willingness to go to war is frequently discussed in the literature. For example, Rohner, Thoenig, and Zilibotti (2013a) use such an argument to generate a random war that is out of the control of people. Jackson and Morelli (2007) argue that if the political process is captured by a biased political elite, then the war occurs against the interest of people. Here we offer an explanation for why the elite is more eager to go to war than the people. One reason is the fear of political turnover. But there is another reason, which is the fear of revolution when trust is high. This second reason will be discussed in section 3.5 where we present the dynamic model.

3.4.3 Equilibrium Outcomes

Given the incomes of agents, we can discuss the choices of the elite and the I people for different levels of trust. This is summarized formally in the following proposition.

Proposition 1. *If trust is sufficiently low ($p \leq p^W$), both the elite and the incumbent people prefer war over peace. The elite is more eager to go to war than the people. Namely, if trust is in the interval $\left[p^W, p_E^W\right]$, then the elite prefers war to peace while incumbent people prefer peace. Moreover, if trust is high enough, i.e., $p \geq p^R$, incumbent people prefer revolution to peace.*

The cut-off values of trust, p^W, p_E^W, and p^R, can be ranked from low to high given certain values of the cost parameters f^R and f_E^R. In the case where f^R and f_E^R are sufficiently large, we have $p^W < p_E^W < p^R$, and the elite never prefers revolution to peace. By sufficiently large costs, we mean $f^R > \underline{f^R}$ and $f_E^R > \underline{f_E^R}$, where the expressions for $\underline{f^R}$and $\underline{f_E^R}$ are given in the appendix. Then, the equilibrium outcomes for all p can be characterized. We summarize this in the next proposition (proof in the appendix) and it is illustrated in Figure 3.2.

Proposition 2. *Given that $f^R > \underline{f^R}$ and $f_E^R > \underline{f_E^R}$, we have $p^W < p_E^W < p^R$, and the equilibrium outcomes for different levels of p (from low to high) are given by the following four cases.*

$p < p^W$: *war. Both elite and incumbent people prefer war, since the expected trade surplus under peace is too low.*

$p^W < p < p_E^W$: *war. Though incumbent people prefer peace given the large trade surplus, the elite decides to stay at war. The elite has more to lose if there is a political turnover.*

$p_E^W < p < p^R$: *peace. There is enough trade surplus to gain and no threat of revolution. The elite prefers peace and so do incumbent people.*

$p > p^R$: *revolution. The expected trade surplus is so large that incumbent people decide to revolt. The elite is overthrown and democracy is established. The elite never prefers revolution.*

If p is at the threshold level $p = p_E^W$, then the equilibrium outcome can be either war or peace, because the elite is indifferent between the two states and pure strategies and mixed strategies between war and peace can all be equilibria. The analogous result holds for the case $p = p^R$.

The revolution occurs when trust is too high. This implies that the elite may have an incentive to prevent trust from getting too high. Starting a conflict and thus preventing the updating of beliefs during trade interactions gives the elite a way of limiting trust. The dynamic model in section 3.5 allows discussing how the elite can apply this divide-and-rule strategy.

3.5 The Dynamic Model

In this section, we consider a dynamic model that includes the evolution of trust. With this model, we study under which circumstances the elite wants to decrease the trust between the two ethnic groups, or equivalently, polarize the society. The elite seeks to influence trust because trust affects the decisions of people to revolt, which in turn influence the income of the elite.

3.5.1 Environment

We assume that the elite lives for infinite periods and is forward-looking. Each cohort of people lives for only one period and in the next period a new cohort of people are born.

The assumption that people care only about the current period income simplifies the analysis substantially. Although people's decision on revolution or peace will be different from the current setting if we were to assume that people are forward-looking, we expect the key results of the model to still hold – as long as they still prefer revolution to peace when trust is sufficiently high. We show after the presentation of the dynamic model that this is plausible.

Each period of the dynamic model includes everything that happens in the static model. Moreover, the evolution of the political system and trust over the periods follows the rules below. If democratization occurs in one period, democracy is set up and consolidated for all the periods afterwards. The equilibrium in all these periods will be laissez faire, such that people of both groups simply gain their home production income and the trade surplus. If autocracy survives this period, the next period starts with autocracy.

The dynamics of trust follow the following rule. First, in the beginning of each period, trust is p, i.e., the common belief about the probability that the relation between the two groups is "beneficial". Then, if trade occurs in this period, agents update their belief about the relation after observing the trade outcome, i.e. they update their belief of trust using Bayes' rule. If there is no trade, agents learn nothing about the type of relation. Finally, at the end of each period, there is some probability that the type of the relation switches. The stochastic types are driven by cultural shifts, which can be related to social structure, population mixture, and so on (see Tabellini, 2008, and Rohner, Thoenig, and Zilibotti, 2013a). For example, consider a case where in the beginning both groups consist of mainly young people. Their skills are not complementary with each other and the interactions and trade between young people are full of frictions. Some time later, the population of one group becomes older due to different demographic trends, while the other group stays the same. Now their skills are complementary, since the old group brings in experience and knowledge while the young group contributes for example creativity and energy. The relation between the two groups thereby becomes beneficial and trade and cooperation are more likely to generate good outcomes. More specifically, we assume that the type of the relation follows a two-state first-order stochastic Markov process with the following transition matrix:

	t	B	H
$t-1$			
B		$1-\psi$	ψ
H		ϕ	$1-\phi$

where B and H denote the types of the relation being "beneficial" and "harmful", respectively, and ψ and ϕ are the probabilities that the type changes, conditional on the relation being "beneficial" or "harmful", respectively. Agents are aware of the possibility that types can switch. This implies that agents change their belief even if there was no trade, because they anticipate that the nature of the relation may have switched.

How does trust change when there is a political turnover? We assume that turnover doesn't affect trust. This is a fairly natural assumption in our setting. Trust is the common belief about the probability of the relation being beneficial, based on the common observations of past trade outcomes. It should therefore be the same for both ethnic groups, either as incumbent or opponent.

We also assume that after the turnover, the elite of the old incumbent group loses its rents and exits the economy. If some periods later, this group becomes the incumbent group again, then a new cohort of elite is ruling. Therefore, the current elite's continuation value only comes from the consecutive periods that it stays in power without turnover.

3.5.2 Solution

In the beginning of each period, we still denote the variables of the incumbent group with subscript I, and the variables of the opponent group with subscript O. If at the end of this period the incumbent group becomes opponent, we still keep the subscript I to denote the (new) incumbent, but keep in mind that the values of the variables changes. For instance, in the period when group A is the incumbent group, y_I takes the value of the home-production income of people A, while in the next period when group B is the incumbent group, y'_I takes the value of the home-production income of people B, which can be different from y_I.

The incomes and the choices of people are exactly the same as in the static model as each cohort lives for only one period. Therefore, if $p > p^R$, I people choose revolution, otherwise the elite stays in power and sets government policies. Essentially, this is what we need to know about the people. This is why, if people were to live for infinite periods, we would expect the results of the model not to be too different – as long as people choose to revolt when trust is very high.

We now show how trust evolves. Lets say that initially trust is at some level p at the beginning of the period and that trade takes place. Then, all agents update their belief according to Bayes' rule based on the trade outcome, either in democracy or in autocracy with peace, i.e.

$$p^+ = \begin{cases} \frac{pq_H}{pq_H+(1-p)(1-q_L)} & \text{if } y_T = y_H, \\ \frac{p(1-q_H)}{p(1-q_H)+(1-p)q_L} & \text{if } y_T = y_L. \end{cases}$$

If there is no trade due to the war, then there is no new information about the type of the relation, so the belief stays the same at this moment, i.e. $p^+ = p$. But at the end of the period, the stochastic shock to the type of the relation realizes. After that, the belief that the type is "beneficial" becomes $p' = p^+ (1-\psi) + (1-p^+)\phi = p^+ (1-\psi-\phi) + \phi$, and this is also the level of trust at the beginning of the next period. The evolution of trust across two periods is summarized below:

$$p' = \begin{cases} (1-\psi-\phi)\, p + \phi & \text{if } s = W, \\ (1-\psi-\phi)\, \frac{pq_H}{pq_H + (1-p)(1-q_L)} + \phi & \text{if } s = P, y_T = y_H, \\ (1-\psi-\phi)\, \frac{p(1-q_H)}{p(1-q_H)+(1-p)q_L} + \phi & \text{if } s = P, y_T = y_L. \end{cases}$$

We can see that if war continues for infinitely many periods, trust converges to the "natural" level $\frac{\phi}{\phi+\psi}$ with the auto-correlation $(1-\psi-\phi)$. We want the probability of the change of types not to be too high and the "natural" level of trust not to be too low nor too high, such that people prefer peace at this level. We therefore maintain the following assumption:

Assumption 2. $\psi \leq \frac{1}{2}$, $\phi \leq \frac{1}{2}$ *and* $\frac{\phi}{\phi+\psi} \in \left[p^W, p^R\right]$.

If revolution happens, then the equilibrium outcomes are just a repetition of the case of revolution in the static model. If there is no revolution, then in autocracy the elite's choice sets are the same as in the static model: war or peace, tax and transfer. Tax and transfer are trivially determined by the maximal tax rate and the minimal transfer, as in the static model. However, when the elite decides on war or peace, it now maximizes the expected life-time income, given the current period's level of trust:

$$V(p) \quad = \quad \begin{cases} \max_{s \in \{W,P\}} y_E^s(p) + \beta \pi^s E^s V(p'), & \text{if } p \leq p^R, \\ -f_E^R, & \text{if } p > p^R, \end{cases}$$

where y_E^s is the elite's current period income, π^s is the probability that the current incumbent group stays in power (both depending on $s \in \{W, P\}$), p' is the level of trust in the next period, and β is the discount factor. From this follows the law of motion discussed above.

We can characterize important properties of the value function and of its solution, given certain conditions and a value of p. We can for example consider the cases when (1) both the cost of war and trust are low, or (2) when both the cost of revolution for the elite and trust are high. We discuss the elite's behavior and the equilibrium outcomes in each of these cases.

First, when trust and the cost of war are both low enough, then there is not much to gain from peace and trade, and the loss from going to war is small. Moreover, war implies a lower chance of political turnover compared to peace, which increases the elite's expected income both this period and in the future. This property can be summarized in the following proposition (proof in the appendix).

Proposition 3. *Suppose that* $f^W < \frac{\pi^W - \pi^P}{\pi^W}(y_I + y_O)$*, then when* p *is sufficiently low, the elite wages war. More precisely, for* $p = 0$*, the elite chooses war; and if* $V(p)$ *is continuous at* $p = \phi$*, then there exist a* $p_E^W > 0$*, such that for all* $p < p_E^W$*, war is chosen as well.*

Second, consider the following scenario: in a given period, trust is relatively high, peace is chosen by the elite, trade occurs between the two groups for many periods, and there are enough good trade outcomes such that trust keeps increasing. The increasing trust raises the trade surplus and income of people in peace, but is it good news for the elite? Not necessary. While the high level of trust implies gains from trade and thus large resources in the society that the elite can potentially extract, it is also a threat to the elite, since a too high level of trust may trigger a revolution. In particular, when $p > p^R$, I people find that cooperating with O people in democracy (where they are not taxed by an elite) is better than autocracy (in which they extract income from the O people but are also being expropriated by their own elite). If p is large enough and very close to p^R, choosing peace means that with some positive probability the trade outcome will be good. Then, p may increase to a level higher than p^R, which will trigger a revolution in the next period. Since revolution implies a high cost for the elite, it can be optimal for the elite to choose war instead of peace even when trust is already high, since during the war the trust is expected to regress back to the natural level p_0 where there is no risk of revolution. To avoid that trust can grow above this critical level after sufficiently many good trade outcomes, the elite can strategically start a war to prevent people from seeing good trade outcomes. In the appendix, we derive the "sufficiently large" cost of revolution as $\underline{f_E^R} \doteq \frac{\pi^P(1-\theta)\tau(y_I+y_O+2p^R) - \pi^W(1-\theta)\tau(y_I+y_O-f^W) + \beta\pi^P\left(1-q^R\right)\bar{V} - \beta\pi^W \underline{V}}{\beta\pi^P q^R}$. Then we have the following proposition (proof in the appendix):

Proposition 4. *Suppose that* $f_E^R > \underline{f_E^R}$*, then if* p *is sufficiently large, the elite chooses to wage war, while people would prefer peace. The war not just prevents trust from growing, but it leads to declining trust. The elite increases polarization and reduces the interaction between the two groups in order to increase its own probability of staying in power. More precisely, when* $p = p^R$*, then the elite prefers war over peace; and there exists a* $p_E^R < p^R$*, such that for all* $p > p_E^R$*, the elite chooses war.*

In this case, war occurs when trust is high and when there is a lot to gain from trading in peace. This is an interesting result, since high trust makes peace more attractive for the society overall. The reason for this result is that the elite's interest is different from the interest of the society and of the people. It is true that the higher level of trust generates larger total income in the whole society, but it also changes the allocation of income by triggering a revolution, which reduces the income of the elite drastically. This is the second reason why the elite decides to go to war and to stop the trade interaction against the interest of people: the fear of an increase in trust and of the revolution that this may trigger.[13]

If war starts and trade is interrupted at a high level of trust, then there is no chance of a further increase in trust. Although the termination of trade between the two ethnic groups does not directly harm trust, it in fact prevents the potential growth of trust. Trust during war gradually converges back to its natural level which is lower than the threshold where a revolution can occur. This means that after the elite purposely stops trade, polarization can increase. This strengthens the power of the elite and prevents revolution. This is one of the key findings of this paper and it represents the divide-and-rule strategy that has frequently been described as a source of ethnic tensions.

Given the conditions in the propositions above, the dynamic model generates certain results that are similar to the ones in the static model in the following respects. First, if the cost of war is sufficiently small, the elite chooses to go to war when trust is low, because the benefit from peace, i.e., the trade surplus, is expected to be low. The incumbent group fights with the opponent group in order to stay in power with higher probability. Second, if trust is too high, I people prefer revolution and democracy together with O people, in which they benefit from the expected high trade surplus and are no longer expropriated by the elite. Such a revolution is very costly for the elite since they lose all their rents. While in the static model trust is exogenously given, the dynamic model allows us to analyze how trust evolves. More importantly, the dynamic model allows us to see how the elite strategically influences trust. The elite achieves this by going to war in order to stop further increase in trust, which otherwise would lead to revolution.

How does trust evolve over time? If trust is very low, then the elite (and also the incumbent people) prefer to be at war with the other group. In the absence of trade interactions during the war, trust regresses to the natural level due to the stochastic switch of types. After some periods, trust may reach a level that can lead to peace. Then, if there are sufficiently many good trade outcomes during peace, trust rises further. But if trust becomes so high that the elite sees the potential of a revolution in the near future, then it wages a war again to stop trade. During the war there are again no trade interactions. This war, in a situation when the level of trust is high, is at the cost of the people and the society. But it helps the elite to stay in power, since it keeps trust low (and thus polarization high), so that the incumbent people do not have sufficient common

[13]Recall from the discussion of the static model that the other reason why the elite is more likely to go to war than the people is that they have more to lose from a transition of power to the other group.

interest with the other group to revolt against the own elite. During the war, trust may regress down due to the stochastic relation type such that there is no threat of revolution anymore. Then, the elite may stop the war and allow trade again.

This model helps us to understand some of the most disturbing episodes of violence in recent history. As we have shown in Section 3.3, elites in Rwanda and Yugoslavia have purposely destroyed the common interest of people in order to maintain or increase their power. This destruction of the common interest often took the form of ethnic violence which hampered trust. The lack of trust then triggered further violence between groups who thought that they have little to gain from peaceful interaction. Our model provides an explanation for why rational people follow leaders into destructive violence. Some previous approaches to answering this question have assumed that elites can directly manipulate people's beliefs (for example Posner, Spier, and Vermeule, 2010). In contrast, agents in our model are perfectly aware of other agents strategies. The elite's ability to initiate conflict to prevent economic interaction allows it to induce people to polarise by affecting trust between people of different groups.

3.6 Conclusion

We propose a theory of divide-and-rule where political elites strategically initiate conflicts between ethnic groups in order to polarize society and thus sustain their own power. We model polarization as a lack of trust that is shaped by trade interactions between agents of the different ethnic groups. The elite can prevent trust from emerging by starting a conflict that interrupts trade. The elite follows this strategy when there is a threat of revolution. The model also generates that an elite is more likely to seek war than the people. This is the case because the elite has the double fears of losing power to the other group and to be overthrown by the own group if the common interest between groups becomes too large.

We document that our model is consistent with a number of cases of large-scale ethnic violence, in particular with the incidents in Rwanda and Yugoslavia. These cases show that polarization was not simply exogenously given, but to some extent *constructed* by power-seeking elites. Violence often had the goal of destroying trust and creating instability. This allowed elites to exercise their power more freely. An implication of these observations is that treating conflicts as "inherently ethnic" may be misleading. Our model shows the elite's role in creating ethnic polarization and it therefore enables us to discuss possible counter-measures. Generally speaking, attempts to prevent ethnic violence should pay considerable attention to the role of the elite. Promising ways to achieve this would be to reduce elites' incentive or ability to reduce trust. This is especially important in cases where the elite may attempt to do so because they are threatened by a *high* level of trust. In such cases, the interests of the elite diverge from those of society overall, since the elite values being in power more than possible gains from trade.

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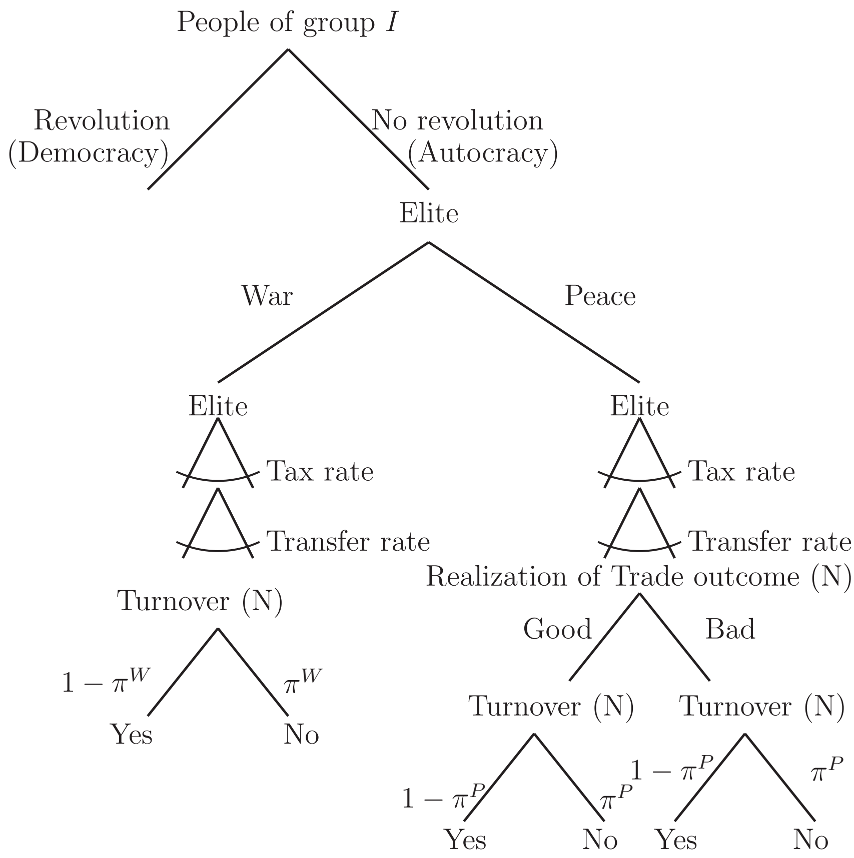
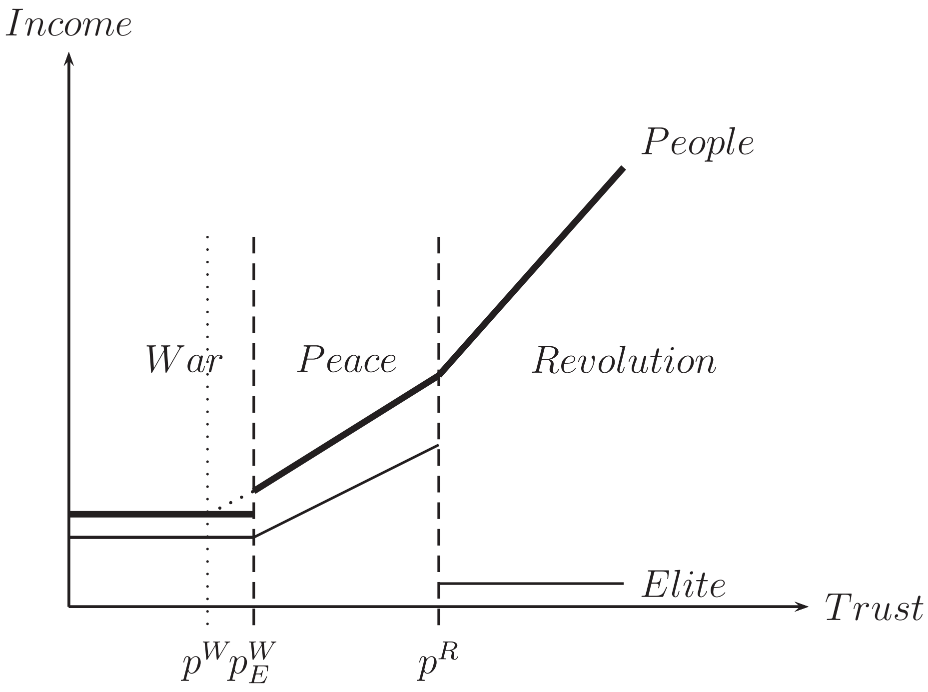
3.8 Figures

Figure 3.1: Game Tree



The figure shows the timing in the baseline model. (N) denotes nature.

Figure 3.2: Trust and Income



The figure shows the relationship between trust and income. The thin solid lines refers to the elite, while the thick solid line represents the people. The dashed lines separate the different states of the world. The dotted line marks the threshold level of trust where people would prefer peace over war. The jump in people's income at the switch from war to peace is due to the timing of the switch, since the people would have higher income from peace already at lower levels of trust, while the elite decides to stay at war.

Part III

Appendices

A Appendix to Chapter 1: Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development

A.1 Model Details

This appendix provides a detailed discussion of the model presented in Section 1.5. The framework is based on Donaldson and Hornbeck (2013) and Eaton and Kortum (2002).

Donaldson and Hornbeck (2013) derive a reduced form expression for the impact of railroads on land values from general equilibrium trade theory. I adapt their framework to a version which can be estimated with satellite data and digitized geographic data alone, thus making it suitable for my estimation and counterfactual analysis across 590 Indian districts. Furthermore, I focus on the case with immobile labor as this is the more realistic assumption during the 9-year period which I consider.

The basic setup is a Ricardian trade model as in Eaton and Kortum (2002) with the immobile production factors land and labor and the mobile factor capital. The economy consists of many trading regions (Indian districts), where the origin of a trade is indexed by o and the destination by d.

A.1.1 Preferences

Consumers have CES preferences over a continuum of differentiated goods indexed by j,

$$U_o = \left(\int_j x_o(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}},$$

where $x_o(j)$ is the quantity consumed of variety j by a consumer in district o and $\sigma > 0$ is the elasticity of substitution between goods. Consumers in location o maximize U_o subject to

$$\int_j p_o(j) x_o(j) dj = y_o$$

where y_o is income per capita in district o. This yields a demand function for variety j equal to

$$x_o(j) = \frac{y_o}{P_o}\left(\frac{p(j)}{P_o}\right)^{-\sigma},$$

where P_o is the a CES price index of the form

$$P_o = \left(\int_j p_o(j)^{1-\sigma} dj\right)^{\frac{1}{1-\sigma}}.$$

Indirect utility of a consumer who has income y_o and faces a vector of prices $\boldsymbol{P_o}$ then is

$$V(\boldsymbol{P_o}, y_o) = \frac{y_o}{P_o}.$$

A.1.2 Production Technology

Each district produces intermediate goods with a Cobb-Douglas technology using land (L), labor (H), and capital (K),

$$x_o(j) = z_o(j)\big(L_o(j)\big)^{\alpha}\big(H_o(j)\big)^{\gamma}\big(K_o(j)\big)^{1-\alpha-\gamma},$$

where the amounts of land and labor in o are fixed but capital is mobile across districts. $z_o(j)$ is an exogenous productivity shifter as explained below. The production function implies marginal costs

$$MC_o(j) = \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)},$$

where q_o is the land rental rate, w_o is the wage, and r_o is the interest rate. Following Eaton and Kortum (2002), each district draws its productivity $z_o(j)$ from a Fréchet distribution with CDF

$$F_o(z) = Pr[Z_o \leq z] = \exp(-T_o z^{-\theta}),$$

where $\theta > 1$ governs the variation of productivity within districts (comparative advantage) and T_o is a district's state of technology (absolute advantage).

A.1.3 Transport Costs and Prices

Trade costs between locations o and d are modeled according to an "iceberg" assumption: for one unit of a good to arrive at its destination d, $\tau_{od} \geq 1$ units must be shipped from origin o. This implies that if a good is produced in location o and sold there at the price $p_{oo}(j)$, then it is sold in location d at the price $p_{od}(j) = \tau_{od} p_{oo}(j)$.

We assume perfect competition such that prices equal the marginal costs of producing each variety:

$$\begin{aligned} p_{oo} &= MC_o(j) = \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)} \\ p_{od} &= \tau_{od} MC_o(j) = \tau_{od} \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)} \\ z_o(j) &= \tau_{od} \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{p_{od}} \end{aligned} \tag{A.1}$$

Consumers search for the cheapest price of each variety, such that the distribution of prices is governed by the productivity distribution. Eaton and Kortum (2002) show, by substituting Equation (A.1) into the distribution of productivity, that district o offers district d a distribution of prices

$$\begin{aligned} G_{od}(p) = Pr[P_{od} \leq p] &= 1 - F_o\left[\tau_{od} \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{p}\right] \\ &= 1 - \exp\left[- T_o\big(\tau_{od} q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}\big)^{-\theta} p^{\theta}\right]. \end{aligned}$$

District d buys variety j from another district if at least one district offers a lower price than itself. The distribution of prices for what district d purchases then is

$$G_d(p) = P[P_d \leq p] = 1 - \prod_o \{1 - G_{od}(p)\}.$$

Inserting for $G_{od}(p)$ yields

$$\begin{aligned} G_d(p) &= 1 - \prod_o \{\exp\big[- T_o\big(\tau_{od} q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}\big)^{-\theta} p^{\theta}\big]\} \\ &= 1 - \exp\left[- \sum_o \big[T_o\big(\tau_{od} q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}\big)^{-\theta}\big] p^{\theta}\right] \\ &= 1 - \exp\left[- \Phi_d p^{\theta}\right] \end{aligned}$$

where the destination-specific parameter $\Phi_d = \sum_o \big[T_o\big(\tau_{od} q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}\big)^{-\theta}\big]$ summarizes the exposure of destination d to international technology, factor costs, and trade costs.

Eaton and Kortum (2002) show that the price index takes the form

$$P_d = \gamma \Phi_d^{-\frac{1}{\theta}} \tag{A.2}$$

with

$$\gamma = \left[\Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)\right]^{\frac{1}{1-\sigma}},$$

where Γ is the Gamma function. The rental rate for capital is equalized everywhere to $r_o = r$ because capital is perfectly mobile. Donaldson and Hornbeck (2013) then define

$$\kappa_1 = \gamma^{-\theta} r^{-(1-\alpha-\gamma)\theta}$$

and rearrange Equation (A.2) to

$$\begin{aligned} P_d^{-\theta} &= \kappa_1 \sum_o \left[T_o\left(\tau_{od} q_o^\alpha w_o^\gamma\right)^{-\theta}\right] \\ &= \kappa_1 \sum_o \left[T_o\left(q_o^\alpha w_o^\gamma\right)^{-\theta} \tau_{od}^{-\theta}\right] \\ &\equiv CMA_d. \end{aligned} \tag{A.3}$$

They refer to CMA_d as "consumer market access" because it measures district d's access to cheap goods (i.e. low production costs in supplying district and low trade costs).

A.1.4 Trade Flows and Gravity

Eaton and Kortum (2002) show that the fraction of expenditure of district d on goods from district o is

$$\begin{aligned} \frac{X_{od}}{X_d} &= \frac{T_o\left(q_o^\alpha w_o^\gamma r^{1-\alpha-\gamma}\right)^{-\theta} \tau_{od}^{-\theta}}{\Phi_d} \\ &= \frac{T_o\left(q_o^\alpha w_o^\gamma r^{1-\alpha-\gamma}\right)^{-\theta} \tau_{od}^{-\theta}}{\sum_o \left[T_o\left(q_o^\alpha w_o^\gamma r^{1-\alpha-\gamma}\right)^{-\theta} \tau_{od}^{-\theta}\right]}. \end{aligned} \tag{A.4}$$

Assuming that aggregate expenditures equal aggregate income ($X_d = Y_d$) and canceling out the interest rate, this can be rearranged to

$$\begin{aligned} X_{od} = &\underbrace{T_o\left(q_o^\alpha w_o^\gamma\right)^{-\theta}}_{\text{Origin's productivity and factor costs}} \\ &\times \underbrace{Y_d}_{\text{Destination's income}} \\ &\times \underbrace{\left(\sum_o \left[T_o\left(q_o^\alpha w_o^\gamma\right)^{-\theta} \tau_{od}^{-\theta}\right]\right)^{-1}}_{\text{Destination's CMA}} \underbrace{\tau_{od}^{-\theta}}_{\text{Trade costs}}. \end{aligned}$$

Using Equation (A.3), the competitiveness of the destination's market can be written as

$$\sum_o \left[T_o\left(q_o^\alpha w_o^\gamma\right)^{-\theta}\tau_{od}^{-\theta}\right] = \frac{CMA_d}{\kappa_1},$$

which yields

$$\begin{aligned} X_{od} &= \underbrace{T_o\left(q_o^\alpha w_o^\gamma\right)^{-\theta}}_{\text{Origin's productivity and factor costs}} \\ &\times \underbrace{Y_d}_{\text{Destination's income}} \\ &\times \underbrace{\kappa_1 CMA_d^{-1}}_{\text{Destination's CMA}} \underbrace{\tau_{od}^{-\theta}}_{\text{Trade costs}} \end{aligned} \tag{A.5}$$

A.1.5 Consumer market access and firm market access

Equation (A.5) is a gravity equation with the standard features that trade increases in income of the destination and in productivity of the origin, while trade decreases in production costs, trade costs, and in consumer market access of the destination. Summing the gravity equation over destinations d yields total income of origin o,

$$\begin{aligned} Y_o = \sum_d X_{od} &= \kappa_1 T_o(q_o^\alpha w_o^\gamma)^{-\theta} \sum_d \left[\tau_{od}^{-\theta} CMA_d^{-1} Y_d\right] \\ &= \kappa_1 T_o(q_o^\alpha w_o^\gamma)^{-\theta} FMA_o, \end{aligned} \tag{A.6}$$

where Donaldson and Hornbeck define "firm market access" of district o as

$$FMA_o \equiv \sum_d \tau_{od}^{-\theta} CMA_d^{-1} Y_d. \tag{A.7}$$

FMA_o depends positively on all other destination's income Y_d and negatively on their CMA_d (since a higher consumer market access in d implies that district o faces more competition when exporting to d). Using Equation (A.6), one can obtain

$$\frac{Y_o}{\kappa_1 FMA_o} = T_o(q_o^\alpha w_o^\gamma)^{-\theta}$$

which can be substituted into the definition of CMA_d to obtain

$$\begin{aligned} CMA_d &= \kappa_1 \sum_o T_o (q_o^{\alpha} w_o^{\gamma})^{-\theta} \tau_{od}^{-\theta} \\ &= \sum_o \tau_{od}^{-\theta} FMA_o^{-1} Y_o \\ CMA_o &= \sum_d \tau_{od}^{-\theta} FMA_d^{-1} Y_d. \end{aligned} \tag{A.8}$$

Following Donaldson and Hornbeck (2013), if trade costs are symmetric, then a solution to the Equations (A.7) and (A.8) must satisfy $CMA_o = FMA_o$ and they refer to this term as "market access", such that

$$MA_o = \sum_d \tau_{od}^{-\theta} MA_d^{-1} Y_d. \tag{A.9}$$

This system of non-linear equation captures the general equilibrium effects of the bilateral trade costs τ_{od}, because a decline in the trade costs of d enters in MA_d and will have an effect on the market access measure of o.

A.1.6 Measuring real market access with light

I adapt the approach of Donaldson and Hornbeck (2013) to incorporate light as a measure for real income. The starting point is Equation (A.9). I then use the fact that the sum of light in a district o measures aggregate real economic activity

$$Y_d = Y_d^r \times P_d$$

such that

$$MA_o = \sum_d \tau_{od}^{-\theta} MA_d^{-1} P_d Y_d^r$$

Using the formula for the price index,

$$P_d = MA_d^{-\frac{1}{\theta}},$$

I obtain

$$MA_o = \sum_d \tau_{od}^{-\theta} MA_d^{\frac{-(1+\theta)}{\theta}} Y_d^r.$$

A.1.7 Income and Market Access with Immobile Labor

Donaldson and Hornbeck (2013) proceed to solve Equation (A.6) for land prices. I instead solve for real income, which in the empirical analysis I can approximate with luminosity. Using that result that firm market access equals consumer market access, this yields

$$Y_o = \kappa_1 T_o (q_o^{\alpha} w_o^{\gamma})^{-\theta} MA_o \tag{A.10}$$

where income is a function of productivity, factor prices, and market access. Note that the constant κ includes the interest rate, which is equalised across districts because of full capital mobility. The rental rates for the immobile factors land and labor are related to their income share according to the Cobb-Douglas production function, such that

$$\begin{aligned} q_o L_o &= \alpha Y_o \\ w_o H_o &= \gamma Y_o. \end{aligned}$$

Using this in Equation (A.10) and solving for income yields

$$Y_o = \left(\kappa_1 T_o\right)^{\frac{1}{1+\theta\alpha+\theta\gamma}} \left(\frac{\alpha}{L_o}\right)^{\frac{-\theta\alpha}{1+\theta\alpha+\theta\gamma}} \left(\frac{\gamma}{H_o}\right)^{\frac{-\theta\gamma}{1+\theta\alpha+\theta\gamma}} \left(MA_o\right)^{\frac{1}{1+\theta\alpha+\theta\gamma}} \tag{A.11}$$

Furthermore, luminosity measures real economic activity. I therefore use the relationship between the price index and market access,

$$P_o = MA_o^{-\frac{1}{\theta}},$$

to obtain

$$\frac{Y_o}{P_o} = \left(\kappa_1 T_o\right)^{\frac{1}{1+\theta\alpha+\theta\gamma}} \left(\frac{\alpha}{L_o}\right)^{\frac{-\theta\alpha}{1+\theta\alpha+\theta\gamma}} \left(\frac{\gamma}{H_o}\right)^{\frac{-\theta\gamma}{1+\theta\alpha+\theta\gamma}} \left(MA_o\right)^{\frac{1+\theta(1+\alpha+\gamma)}{(1+\theta\alpha+\theta\gamma)\theta}}$$

After taking logs, the determinants of real income can be grouped into

$$\begin{aligned} \ln\left(Y_o^r\right) &= \underbrace{\frac{1}{1+\theta\alpha+\theta\gamma}\ln\left(\kappa_1\right) - \frac{\theta\alpha}{1+\theta\alpha+\theta\gamma}\ln\left(\frac{\alpha}{L_o}\right) - \frac{\theta\gamma}{1+\theta\alpha+\theta\gamma}\ln\left(\frac{\gamma}{H_o}\right)}_{\text{Constant over districts or time}} \\ &+ \underbrace{\frac{1}{1+\theta\alpha+\theta\gamma}\ln\left(T_o\right)}_{\text{Productivity}} + \underbrace{\frac{1+\theta(1+\alpha+\gamma)}{(1+\theta\alpha+\theta\gamma)\theta}\ln(MA_o)}_{\text{Market access}}. \end{aligned} \tag{A.12}$$

This equation suggests a log-linear relationship between real income and transport infrastructure, where the effect of transport infrastructure goes through the measure of market access. The elasticity of income with respect to market access,

$$\beta = \frac{1 + \theta(1 + \alpha + \gamma)}{(1 + \theta\alpha + \theta\gamma)\theta},$$

can be estimated using variation in income and market access over time.

B Appendix to Chapter 2: Economic Reforms and Industrial Policy in a Panel of Chinese Cities

Joint with Lin Shao and Fabrizio Zilibotti

B.1 Data Sources

Official Statistics: City-Level The main source for the official city statistics are the *China City Statistical Yearbooks*, which cover all prefecture-level cities from 1988 to 2010. Most of the city-level statistics, including nominal GDP, electricity consumption, population, government spending and land area, are taken from this data set. As complementary sources to this data set, we include three other city-level statistical collections. First, we take the GDP data for the years 1992 and 1993 from *New China City in 50 Years Statistical Collection*, since these years are missing in *China City Statistical Yearbooks.* Second, for a subset of cities, we collect GDP and investment data for the period of 1978-1988 from *New China in 60 Year Provincial Statistical Collection.* Third, we obtain additional population and educational attainment data from the *China Population Census* (for the years 1990, 2000, and 2010).

Official Statistics: Province-Level The main source for province-level statistics is the *New China in 60 Years Statistical Collection.* We obtain the province-level price indexes, including the GDP and investment deflator, from this data set.

Light and Digital Maps Light intensity at night, an alternative measure for local economic activities, is provided by the National Geographical Data Center for the period of 1992-2010. Using the digital maps of China, we aggregate the light intensity at the level of cities.[1]

[1] The digital maps for several levels of administrative units of the People's Republic of China from 1992 to 2000 were obtained from the Asian Spatial Information and Analysis Network (ACASIAN), where they were produced by Dr. L. W. Crissman.

The light data are obtained from the National Geographical Data Center.[2] The data is available in cleaned form (taking into account clouds, forest fires, gas flaring, etc.) and on a yearly basis from 1992 to 2010. Light is measured on each pixel of approximately one square kilometer on an integer scale from 0 (no light) to 63 (maximum light). In order to map the light intensity of pixels to the administrative entities of cities, we use digital maps of Chinese cities from 2010.

Light is measured by different satellites over time and they show different light intensities because of differences in their calibration. These differences do not matter for our empirical analysis as they are absorbed by the year fixed effects, but for the descriptive data we calibrate the values ex-post following Elvidge *et al.* (2009).

Establishment of SEZ The information on the establishment of the various zones is taken from three sources. The major source is the website of the Ministry of Commerce.[3] We also use the Information Site of China's Development Zones[4] and the Report of the Ministry of Commerce (2006). From these sources, we can derive the year in which the zone was established, its type, and its location.

B.2 Sample Selection

In our main estimations, we focus on a sample of cities for the years 1988-2010. The sample is unbalanced because of the creation of new cities: in the year 1988 the sample has 170 cities (and prefectures) and this number increases to 276 in the year 2010.[5] Our sample covers all provinces in China except for Tibet, Hainan and the province-level cities Beijing, Shanghai, Tianjin, and Chongqing. We also exclude the cities of the first wave of comprehensive SEZ: Shenzhen, Zhuhai, Shantou and Xiamen.

We discuss below in detail our sample selection criteria. Specifically, we provide reasons for three key choices, 1) time period, 2) prefecture-level cities, and 3) urban core. Notice that in the main body of the paper, for simplicity, we call prefecture-level cities "prefecture" and the urban core "city".

[2]See http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html

[3]See http://english.mofcom.gov.cn.

[4]See http://www.cdz.cn/www/index.asp.

[5]See Table 1 in Chung and Lam (2004) for a more detailed assessment of the increase in the number of cities in China.

Sample Period The GDP data in *China City Statistical Yearbooks* only go back to the year 1988.[6] Although pre-1988 GDP data for a subset of cities are available from other data sources, we do not combine them with the *China City Statistical Yearbooks* data in the main empirical studies, due to their inconsistent definition of cities. The inconsistency is a result of the transformation of the administrative structure of local governments, especially at the city-level, during the past 30 years. Before 1983, the administrative structure consisted of four layers. From the top to the bottom, these are province, municipality, county and village.[7] Starting from 1983, the municipalities were gradually transformed into prefecture-level cities. Broadly speaking, the prefecture-level cities replaced municipalities as the third layer in the administrative structure. However, the transformation often coincided with various other changes, which we lack the data to control for. For example, a county which was part of the previous municipality may not be part of the prefecture-level city that is succeeding it. At the same time, new counties which were previously under the jurisdiction of a different municipality may become part of the prefecture-level city. Therefore, the composition of newly formed cities may differ substantially from that of the preceding municipalities.

Most city-level statistic sources fail to distinguish between municipalities and prefecture-level cities. It is therefore impossible to identify the break-point when the transformation was made using just the time-series of a prefecture-level city. The *China City Statistical Yearbooks* are an exception. A prefecture-level city only starts to appear in the *China City Statistical Yearbooks* as soon a municipalities has been granted the official status of prefecture-level city. Therefore, the *China City Statistical Yearbooks* yields a consistent sample of prefecture-level cities for the period 1988-2010.

Prefecture- and County-Level Cities A prefecture-level city (*di ji shi* in Chinese) is in the new administrative system a level between provinces and counties. A prefecture-level city consists of the urban core ("city") and potentially several surrounding counties and rural areas. As part of the transformation of administrative structures, some counties were promoted into county-level cities (*xian ji shi* in Chinese) after the population exceed a certain threshold. After promotion, they remain at the same administration level as counties, which is one layer below prefecture-level cities. In fact, they were still under the administration of the original prefecture-level government. At the same time, a number of county-level cities were promoted to new prefecture-level cities and thereby cut out of

[6] The earliest city statistical yearbook goes back to 1984. However, the yearbook only starts to report city-level GDP after 1988.

[7] As specified in the 1982 constitution, the structure should only consist of three layers: province, county and village. In reality, however, due to practical reasons, another administrative layer called municipality served as the connection between counties and provinces.

their previous prefecture.

The *China City Statistical Yearbooks* contain statistics for both prefecture-level and county-level cities. To have a consistent definition of cities, we drop the cities that were county-level throughout the sample period. For those cities which were promoted to prefecture-level, we keep only the years after the promotion to prefecture-level city.

Prefecture Area and Urban Core *China City Statistical Yearbooks* report statistics at the level of both the whole prefecture area and the urban core (*shi xia qu* in Chinese). Urban core corresponds to the traditional definition of the urban center, which often consists of several urban districts. The prefecture area covers the whole geographic area of the prefecture, which includes the urban core and the surrounding counties, county-level cities and rural areas.

The distinction between the two statistical areas and its implication for the estimation result deserves discussion. First, urban cores are usually more industrialized than the whole prefecture area. Second, most of the SEZ are located in the suburbans of the urban core (Zeng, 2011).[8] Therefore, by focusing on the urban core (or, more simply, *cities* as we call them in the text), we get a more direct estimation of the effects of SEZ. In some parts of the paper we also report results for the entire prefecture.

Inland Sample When we restrict the sample to cities from inland provinces, we define the following provinces as inland: Anhui, Gansu, Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangxi, Jilin, Ningxia, Qinghai, Shaanxi, Shanxi, Sichuan, Xinjiang, Yunnan, and Inner Mongolia. This classification was not purely based on access to the sea, but also considers whether the provinces were part of the reform wave targeted towards inland regions.

B.3 Level Decomposition

The following paragraphs provide information on the decomposition of real GDP per capita into physical capital per capita, human capital (labor efficiency) and TFP. The decomposition is carried out in the prefecture area, instead of the urban center. This is due to the lack of educational attainment data in the urban center.

Real GDP We use the provincial GDP deflators to obtain the real GDP in prefecture cities. They are calculated using provincial constant and current price GDP series for the period 1988-2008.

[8] In our sample, all of the state level zones were located in the city and not on the surrounding periphery.

Physical Capital Stock We apply the perpetual inventory approach to construct the physical capital stock in each city. The physical capital (K_{ipt}) is the sum of physical capital stock after depreciation and new investment (I_{ipt}), such that

$$K_{ipt} = (1 - \delta_k)K_{ipt-1} + I_{ipt}/deflator_{pt}^{Inv}.$$

The deflator for new investment, $deflator_{pt}^{Inv}$, is province-specific. We set δ_k, the annual depreciation rate for physical capital, to be 0.08.[9]

In order to carry out the perpetual inventory approach, we need a reasonable estimate for the physical capital stock of the initial year, which is the year of 1988 given our sample period.

For a subset of cities whose investment data go back to 1978, we derive the capital stock for those cities in the year 1978 as follows

$$K_{ip1978} = \frac{I_{ip1978}}{g_{1978} + \delta_k},$$

where I_{ip1978} is the new investment in year 1978 and g_{1978} is the average growth rate of real physical capital stock before 1978.[10] This is the steady state formula for physical capital stock of a Solow-type growth model (Caselli, 2005). By doing this, we assume that the economy was in steady state in 1978, which is quite plausible.[11]

For those cities whose investment data begins in 1988, we approximate the initial physical capital stock in 1988 using the same formula

$$K_{ip1988} = \frac{I_{ip1988}}{g_{1988} + \delta_k},$$

where g_{1988} is the average growth rate of physical capital stock before 1988.

Size of Labor Force We use population as an approximation for employment in each city because the number of employed persons reported in the *China City Statistical Yearbooks* has some drawbacks. The most imporant drawback is that there is a huge drop in the number of employed persons in the year 1998, the reason of which is unclear to us. Two reasons could potentially contribute to this huge drop. The first potential reason is

[9]Given the large amount of creative destruction that took place in China, we pick the number to be higher than other cross-country growth accounting exercises, for example Caselli (2005).

[10]The growth rate of real physical capital stock, g_{1978}, is calculated using the national physical capital stock. See the personal website of Kuai Wai Li and Li *et al.* (2009) for the detailed construction of the data.

[11]Notice that our sample starts in 1988, the error of the estimate for initial physical capital stock (1978) would have only marginal impacts on the estimate of the physical capital stock ten years later.

that the reform of state-owned enterprises laid off a large number of redundant workers around 1998.[12] The second reason is that perhaps the definition of employed persons changes on 1998. Specifically, before 1998, the employed persons include people who are registered as workers. After 1998, the number only includes people who are registered and are currently working in that city. [13]

Human Capital Following Hall and Jones (1999), we use the average educational attainment (years of schooling) as an approximation for the level human capital of the cities, such that

$$h_{ipt} = e^{\phi_t(s_{ipt})},$$

where s_{ipt} is the average years of schooling and $\phi_t(.)$ is a piece-wise linear function whose slopes represent the return to schooling. To construct $\phi_t(.)$, we take the estimation for the return to schooling in China over the period 1988-2009 from Li *et al.* (2009).[14]

The only data source that reports city-level education attainment is the *China Population Census*. Therefore, the data is only available for the years 1990, 2000 and 2010. We do a simple linear interpolation (extrapolation if needed) to obtain the approximation of human capital for the other years in our sample period.

TFP At last, we obtain the log TFP using the following formula,

$$\log A_{ipt} = \log \frac{Y_{ipt}}{L_{ipt}} - \alpha \log \frac{K_{ipt}}{L_{ipt}} - (1-\alpha) \log h_{ipt}.$$

where α, the share of capital in the output function, is set to be 0.4.

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[12] According to Dong and Putterman (2003), the labor redundancy rate of SOEs is 30% in 1992.

[13] Wu (2011) provides a detailed discussion of the issues with the employment data.

[14] The estimation is not available for the year 2010. We simply assume that the return to schooling did not change between 2009 and 2010, i.e. $\phi_{2010}(.) = \phi_{2009}(.)$.

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Additional Tables and Figures

Table B.1: Baseline specification clustering at province-reform year level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.190***	0.147***	0.127***	0.117***	0.268***	0.212***	0.181***	0.166***
	(4.15)	(4.37)	(4.57)	(4.26)	(5.43)	(4.57)	(3.71)	(3.24)
Post-reform indicator for province-level zone	-0.000486	-0.00706	0.000497	0.00412	-0.0157	-0.0244	-0.00775	0.00319
	(-0.02)	(-0.34)	(0.02)	(0.19)	(-0.59)	(-0.95)	(-0.29)	(0.12)
Log landarea		0.240***	-0.0325	-0.154***		0.211***	-0.0533	-0.175***
		(6.94)	(-1.42)	(-8.11)		(4.72)	(-1.08)	(-5.19)
Log population			0.692***				0.673***	
			(14.10)				(6.95)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2554	2686	2686
AR2	0.960	0.969	0.975	0.964	0.961	0.965	0.971	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province and reform year level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.2: Pre-and post indicators clustering at province-reform year level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indicator for 3 years before any state-level zone	-0.00764	0.0247	0.0229	0.0221	-0.00543	0.00564	-0.0172	-0.0283
	(-0.27)	(0.83)	(0.94)	(0.91)	(-0.10)	(0.12)	(-0.24)	(-0.31)
Indicator for 2 years before any state-level zone	-0.0147	0.0255	0.0238	0.0230	-0.0429	-0.0221	-0.0400	-0.0487
	(-0.48)	(0.78)	(0.91)	(0.90)	(-0.86)	(-0.50)	(-0.57)	(-0.54)
Indicator for 1 year before any state-level zone	-0.0252	0.0165	0.0161	0.0159	-0.0572	-0.0367	-0.0536	-0.0618
	(-0.79)	(0.48)	(0.60)	(0.61)	(-1.18)	(-0.85)	(-0.77)	(-0.69)
Indicator for year of any state-level zone	-0.00290	0.0213	0.0232	0.0241	-0.0816	-0.0599	-0.0742	-0.0811
	(-0.09)	(0.57)	(0.78)	(0.84)	(-1.55)	(-1.36)	(-1.02)	(-0.87)
Post-reform indicator for any state-level zone	0.180***	0.165***	0.144***	0.134***	0.229***	0.188***	0.143*	0.121
	(3.29)	(3.47)	(4.02)	(3.88)	(4.31)	(3.53)	(1.83)	(1.23)
Post-reform indicator for province-level zone	-0.000807	-0.00645	0.00110	0.00471	-0.0166	-0.0307	-0.00860	0.00215
	(-0.04)	(-0.31)	(0.05)	(0.21)	(-0.61)	(-1.13)	(-0.31)	(0.08)
Log landarea		0.241***	-0.0321	-0.154***		0.197***	-0.0536	-0.175***
		(6.95)	(-1.41)	(-8.07)		(4.44)	(-1.08)	(-5.20)
Log population			0.692***				0.673***	
			(14.13)				(6.97)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2686	2686	2686
AR2	0.960	0.969	0.975	0.964	0.961	0.966	0.970	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province and reform year level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.3: Trend break clustering at province-reform year level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.127***	0.0825***	0.0837***		0.181***	0.0858	0.0972**	
	(4.57)	(3.02)	(3.06)		(3.71)	(1.67)	(2.04)	
Post-reform indicator for province-level zone	0.000497	0.000738	0.000861	0.00219	-0.00775	-0.00668	-0.00768	-0.00996
	(0.02)	(0.04)	(0.04)	(0.10)	(-0.29)	(-0.25)	(-0.28)	(-0.37)
Time trend of reformers (state-level)		0.00548**	0.00595*	0.00656**		0.00855*	0.00262	-0.000951
		(2.39)	(1.82)	(2.04)		(1.85)	(0.32)	(-0.10)
Post-reform trend (state-level)			-0.000747	0.0156**			0.00624	0.0450***
			(-0.18)	(2.15)			(0.62)	(2.78)
Sq. post-reform trend (state-level)				-0.000740**				-0.00182***
				(-2.52)				(-2.96)
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
Control Variables	Y	Y	Y	Y	Y	Y	Y	Y
N	5141	5141	5141	5141	2686	2686	2686	2686
AR2	0.975	0.975	0.975	0.975	0.971	0.971	0.971	0.971

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province and reform year level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.4: Effects of different types of Zones clustering at province-reform year level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for ETDZ	0.220***	0.156***	0.120***	0.104***	0.239***	0.171***	0.0969*	0.0581
	(4.86)	(3.85)	(3.29)	(2.78)	(4.28)	(3.14)	(1.78)	(1.03)
Post-reform indicator for HIDZ	0.117**	0.0794**	0.0755**	0.0736**	0.122***	0.0925*	0.106**	0.113**
	(2.31)	(2.14)	(2.50)	(2.48)	(2.77)	(1.87)	(2.27)	(2.35)
Post-reform indicator for EPZ	0.0412	0.0361	0.0205	0.0131	-0.0123	0.00190	0.0490	0.0738
	(0.99)	(0.96)	(0.60)	(0.36)	(-0.18)	(0.02)	(0.69)	(1.09)
Post-reform indicator for OtherTypes	0.0710	0.0583	0.0898*	0.104**	0.0827	0.174***	0.213***	0.233***
	(0.97)	(0.94)	(1.79)	(2.16)	(1.40)	(3.83)	(4.23)	(4.42)
Post-reform indicator for province-level zone	0.00286	-0.00532	0.00260	0.00649	-0.0158	-0.0297	-0.00878	0.00223
	(0.13)	(-0.26)	(0.12)	(0.29)	(-0.60)	(-1.11)	(-0.32)	(0.08)
Log landarea		0.233***	-0.0361	-0.159***		0.187***	-0.0535	-0.180***
		(6.61)	(-1.57)	(-8.22)		(3.97)	(-1.07)	(-5.22)
Log population			0.686***				0.655***	
			(13.70)				(6.63)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2686	2686	2686
AR2	0.961	0.969	0.975	0.964	0.962	0.967	0.971	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province and reform year level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.5: Decomposition of the effect clustering at province-reform year level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for first state-level zone	0.138***	0.148***	0.00343	0.0825***	0.131***	0.244***	0.00409	0.0442
	(4.84)	(3.36)	(0.94)	(3.08)	(3.00)	(4.02)	(0.75)	(1.33)
Post-reform indicator for first province-level zone	-0.0127	-0.0159	0.00242	-0.0125	-0.0145	-0.0201	0.00448**	-0.00705
	(-0.77)	(-0.48)	(1.46)	(-0.75)	(-0.68)	(-0.39)	(2.19)	(-0.27)
Log landarea	-0.218***	-0.532***	-0.0157***	0.0120	-0.212***	-0.490***	-0.0157***	-0.000134
	(-5.95)	(-9.75)	(-4.19)	(0.36)	(-4.96)	(-7.62)	(-3.60)	(-0.00)
Dependent Variable	log(Y/L)	log(K/L)	log(h)	log(TFP)	log(Y/L)	log(K/L)	log(h)	log(TFP)
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5171	4521	4381	3970	3242	2744	2610	2320
AR2	0.948	0.959	0.957	0.802	0.938	0.954	0.950	0.731

The dependent variables are the logarithms of real GDP per capita column (1) and (5), and the three decomposed components: logarithm of physical capital stock (column (2) and (6)), logarithms of average human capital (column (3)-(7)) and logarithm of TFP (column (4)-(8)), of the prefecture area. All speci.cations include land area, prefecture fixed effect and the interaction of province-year dummies as control variables. T-statistics are reported in parenthesis. Standard errors are clustered at the province and reform year level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regression is carried out for the full sample (column (1)-(4)) and restricted inland sample ((5)-(8)).

Table B.6: Baseline specification clustering at province level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.190***	0.147***	0.127***	0.117***	0.268***	0.212***	0.181***	0.166**
	(3.70)	(3.66)	(3.79)	(3.46)	(4.16)	(3.53)	(2.91)	(2.52)
Post-reform indicator for province-level zone	-0.000486	-0.00706	0.000497	0.00412	-0.0157	-0.0244	-0.00775	0.00319
	(-0.02)	(-0.28)	(0.02)	(0.16)	(-0.57)	(-0.96)	(-0.28)	(0.12)
Log landarea		0.240***	-0.0325	-0.154***		0.211***	-0.0533	-0.175***
		(8.36)	(-1.55)	(-8.34)		(4.66)	(-1.10)	(-4.92)
Log population			0.692***				0.673***	
			(16.53)				(6.66)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2554	2686	2686
AR2	0.960	0.969	0.975	0.964	0.961	0.965	0.971	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.7: Pre-and post indicators clustering at province level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indicator for 3 years before any state-level zone	-0.00764	0.0247	0.0229	0.0221	-0.00543	0.00564	-0.0172	-0.0283
	(-0.21)	(0.65)	(0.81)	(0.84)	(-0.08)	(0.10)	(-0.18)	(-0.22)
Indicator for 2 years before any state-level zone	-0.0147	0.0255	0.0238	0.0230	-0.0429	-0.0221	-0.0400	-0.0487
	(-0.39)	(0.67)	(0.86)	(0.88)	(-0.65)	(-0.38)	(-0.42)	(-0.39)
Indicator for 1 year before any state-level zone	-0.0252	0.0165	0.0161	0.0159	-0.0572	-0.0367	-0.0536	-0.0618
	(-0.60)	(0.40)	(0.54)	(0.57)	(-0.88)	(-0.65)	(-0.56)	(-0.50)
Indicator for year of any state-level zone	-0.00290	0.0213	0.0232	0.0241	-0.0816	-0.0599	-0.0742	-0.0811
	(-0.08)	(0.48)	(0.69)	(0.76)	(-1.18)	(-1.03)	(-0.75)	(-0.63)
Post-reform indicator for any state-level zone	0.180***	0.165***	0.144***	0.134***	0.229***	0.188**	0.143	0.121
	(3.05)	(2.93)	(3.64)	(3.51)	(3.13)	(2.61)	(1.35)	(0.89)
Post-reform indicator for province-level zone	-0.000807	-0.00645	0.00110	0.00471	-0.0166	-0.0307	-0.00860	0.00215
	(-0.03)	(-0.25)	(0.04)	(0.19)	(-0.59)	(-1.11)	(-0.31)	(0.08)
Log landarea		0.241***	-0.0321	-0.154***		0.197***	-0.0536	-0.175***
		(8.52)	(-1.55)	(-8.26)		(4.54)	(-1.12)	(-4.94)
Log population			0.692***				0.673***	
			(16.58)				(6.73)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2686	2686	2686
AR2	0.960	0.969	0.975	0.964	0.961	0.966	0.970	0.961

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.8: Trend break clustering at province level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for any state-level zone	0.127***	0.0825***	0.0837***		0.181***	0.0858	0.0972	
	(3.79)	(2.85)	(2.93)		(2.91)	(1.40)	(1.69)	
Post-reform indicator for province-level zone	0.000497	0.000738	0.000861	0.00219	-0.00775	-0.00668	-0.00768	-0.00996
	(0.02)	(0.03)	(0.04)	(0.09)	(-0.28)	(-0.25)	(-0.28)	(-0.35)
Time trend of reformers (state-level)		0.00548**	0.00595	0.00656*		0.00855	0.00262	-0.000951
		(2.13)	(1.70)	(1.85)		(1.65)	(0.23)	(-0.08)
Post-reform trend (state-level)			-0.000747	0.0156*			0.00624	0.0450**
			(-0.15)	(1.81)			(0.47)	(2.16)
Sq. post-reform trend (state-level)				-0.000740**				-0.00182**
				(-2.39)				(-2.46)
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
Control Variables	Y	Y	Y	Y	Y	Y	Y	Y
N	5141	5141	5141	5141	2686	2686	2686	2686
AR2	0.975	0.975	0.975	0.975	0.971	0.971	0.971	0.971

The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.9: Effects of different types of Zones clustering at province level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for ETDZ	0.220***	0.156***	0.120***	0.104**	0.239***	0.171**	0.0969	0.0581
	(4.63)	(3.36)	(2.89)	(2.47)	(3.39)	(2.45)	(1.45)	(0.83)
Post-reform indicator for HIDZ	0.117*	0.0794*	0.0755*	0.0736*	0.122**	0.0925	0.106*	0.113*
	(1.80)	(1.72)	(2.00)	(2.03)	(2.16)	(1.46)	(1.80)	(1.88)
Post-reform indicator for EPZ	0.0412	0.0361	0.0205	0.0131	-0.0123	0.00190	0.0490	0.0738
	(1.12)	(0.96)	(0.56)	(0.33)	(-0.14)	(0.02)	(0.56)	(0.89)
Post-reform indicator for OtherTypes	0.0710	0.0583	0.0898***	0.104***	0.0827*	0.174***	0.213***	0.233***
	(1.14)	(1.20)	(3.14)	(4.27)	(1.76)	(3.18)	(3.96)	(4.42)
Post-reform indicator for province-level zone	0.00286	-0.00532	0.00260	0.00649	-0.0158	-0.0297	-0.00878	0.00223
	(0.11)	(-0.21)	(0.11)	(0.26)	(-0.63)	(-1.12)	(-0.32)	(0.08)
Log landarea		0.233***	-0.0361	-0.159***		0.187***	-0.0535	-0.180***
		(7.70)	(-1.68)	(-8.25)		(4.00)	(-1.10)	(-4.94)
Log population			0.686***				0.655***	
			(15.20)				(6.37)	
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5160	5143	5141	5141	2692	2686	2686	2686
AR2	0.961	0.969	0.975	0.964	0.962	0.967	0.971	0.961

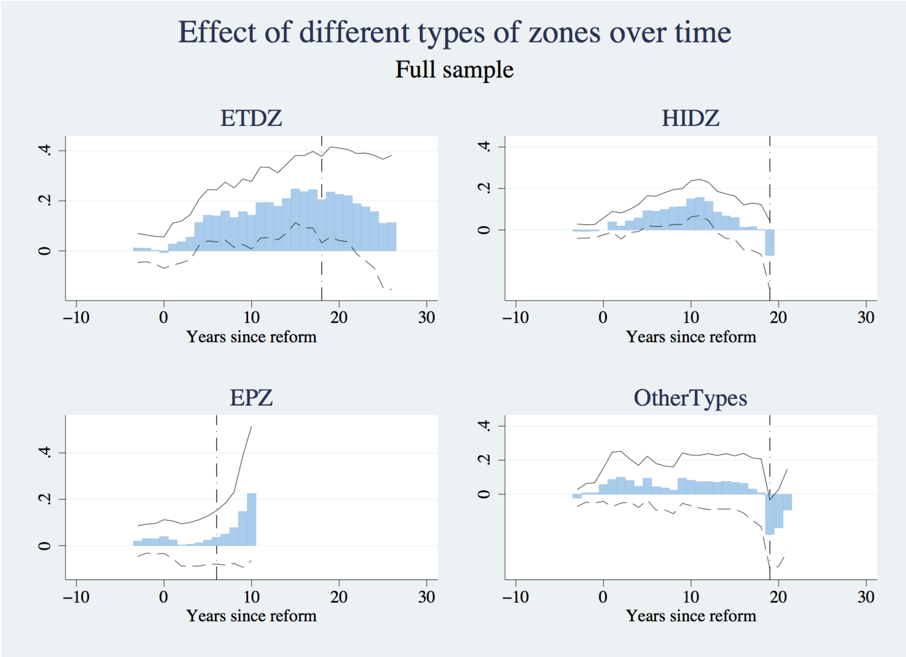
The dependent variable is the logarithm of annual GDP at the city level in columns (1)–(3) and in columns (5)–(7); it is annual GDP per capita at the city level in columns (4) and (8). GDP is measured in current prices. All specifications include city fixed effects and the interaction of province-year dummies. T-statistics are reported in parenthesis. Standard errors are clustered at the province level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regressions in columns (5)–(8) are restricted to cities in 18 inland provinces (as defined in the appendix).

Table B.10: Decomposition of the effect clustering at province level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-reform indicator for first state-level zone	0.138***	0.148***	0.00343	0.0825**	0.131**	0.244***	0.00409	0.0442
	(4.25)	(3.09)	(0.66)	(2.51)	(2.61)	(3.74)	(0.52)	(1.05)
Post-reform indicator for first province-level zone	-0.0127	-0.0159	0.00242	-0.0125	-0.0145	-0.0201	0.00448*	-0.00705
	(-0.63)	(-0.58)	(1.53)	(-0.69)	(-0.61)	(-0.46)	(2.05)	(-0.27)
Log landarea	-0.218***	-0.532***	-0.0157***	0.0120	-0.212***	-0.490***	-0.0157***	-0.000134
	(-5.28)	(-8.48)	(-3.77)	(0.31)	(-4.44)	(-7.10)	(-3.14)	(-0.00)
Dependent Variable	log(Y/L)	log(K/L)	log(h)	log(TFP)	log(Y/L)	log(K/L)	log(h)	log(TFP)
Sample	Full	Full	Full	Full	Inland	Inland	Inland	Inland
N	5171	4521	4381	3970	3242	2744	2610	2320
AR2	0.948	0.959	0.957	0.802	0.938	0.954	0.950	0.731

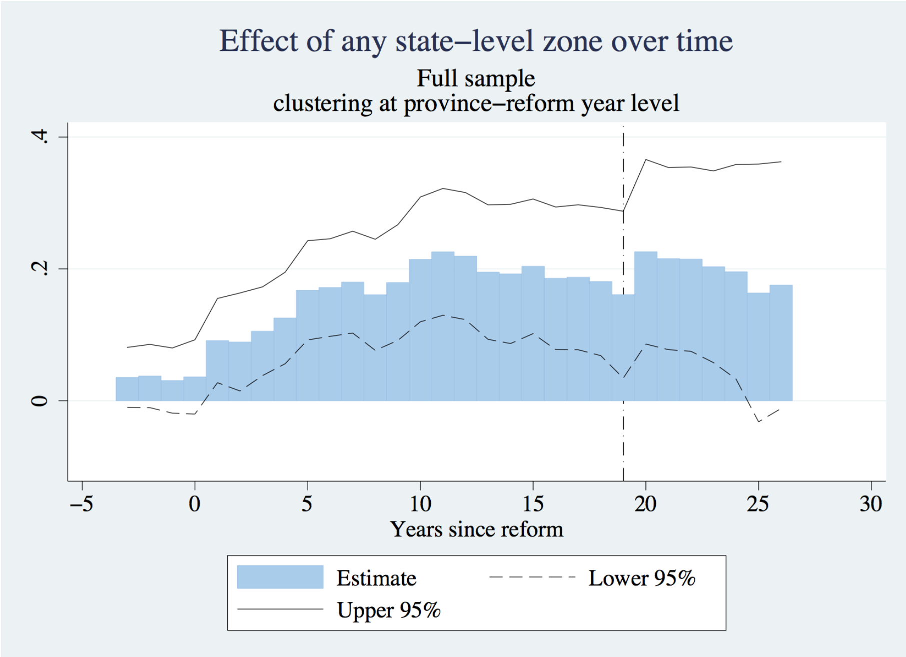
The dependent variables are the logarithms of real GDP per capita column (1) and (5), and the three decomposed components: logarithm of physical capital stock (column (2) and (6)), logarithms of average human capital (column (3)-(7)) and logarithm of TFP (column (4)-(8)), of the prefecture area. All speci.cations include land area, prefecture fixed effect and the interaction of province-year dummies as control variables. T-statistics are reported in parenthesis. Standard errors are clustered at the province level. The sample includes 276 cities from 25 provinces over the sample period 1988-2010 (unbalanced panel). The regression is carried out for the full sample (column (1)-(4)) and restricted inland sample ((5)-(8)).

Figure B.1: Effects of different types of zones over time



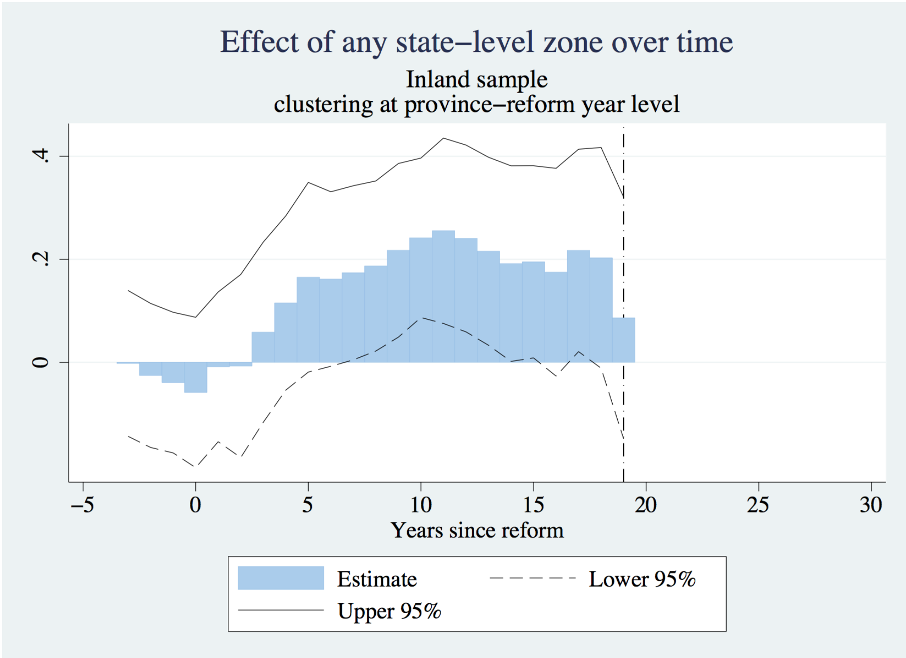
The four panels show the coefficients of different policy variables estimated in the same regression. The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after a type of zone was established. The solid and dashed lines show the confidence intervals. The vertical dashed line shows the lag at which the number of observations drops due to the first zones reaching the end of the sample period. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-year fixed effects. Standard errors are clustered by city. The sample includes 276 cities from 25 provinces for the period 1988-2010.

Figure B.2: Reform effects over time



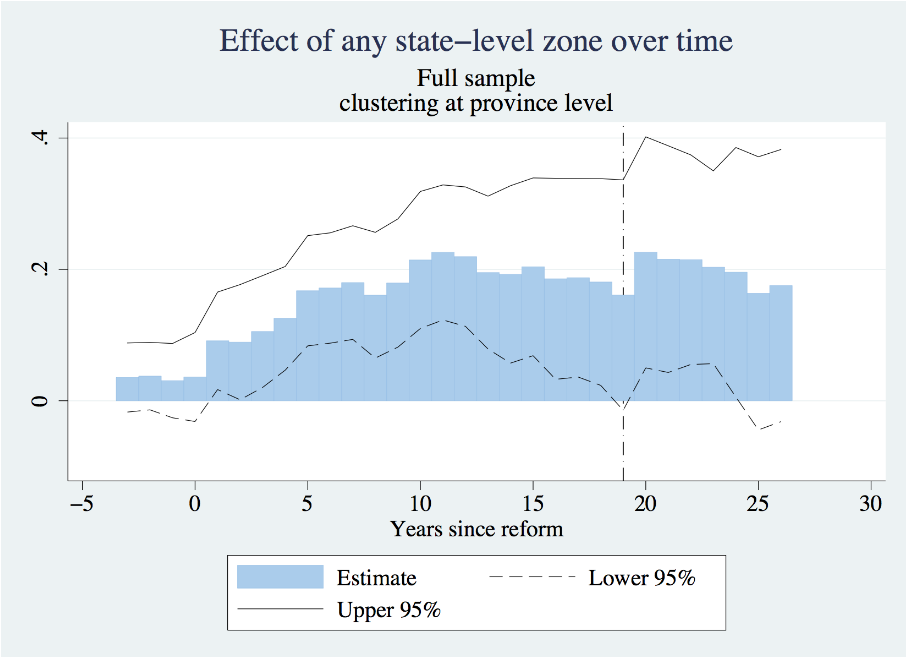
The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after the first zone. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-year fixed effects. Standard errors are clustered by province and reform year. The sample includes 276 cities from 25 provinces for the period 1988-2010.

Figure B.3: Reform effects over time



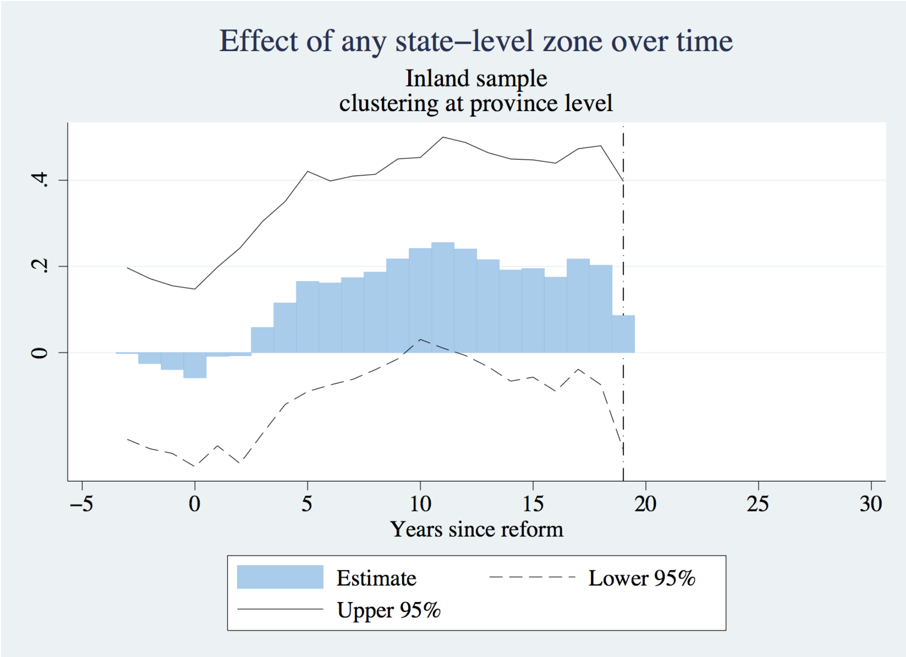
The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after the first zone. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-year fixed effects. Standard errors are clustered by province and reform year. The sample includes 158 cities from 18 inland provinces (as defined in the appendix) for the period 1988-2010.

Figure B.4: Reform effects over time



The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after the first zone. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-year fixed effects. Standard errors are clustered by province. The sample includes 276 cities from 25 provinces for the period 1988-2010.

Figure B.5: Reform effects over time



The bars show the coefficients of a regression of the logarithm of nominal GDP on indicators for years before and after the first zone. The solid and dashed lines show the confidence interval. The vertical dashed line at 19 shows when the reformers from 1991 reach 2010 and subsequently the number of observations to identify post-reform indicators drops to 9. The regression also controls for an indicator for province-level zones, land area, population, city fixed effects, and province-year fixed effects. Standard errors are clustered by province. The sample includes 158 cities from 18 inland provinces (as defined in the appendix) for the period 1988-2010.

C Appendix to Chapter 3: Divide and Rule: An Origin of Polarization and Ethnic Conflict

Joint with Yikai Wang

C.1 Proofs of Propositions

In this appendix, we provide proofs for the propositions and some lemmata that are useful.

First, we prove the propositions in the static model. The results in proposition 1 are already established in the main text. Here we provide the proof for proposition 2, which states the equilibrium outcomes conditional on sufficiently large revolution cost.

Proof. If the cost of revolution for incumbent people is high, then they prefer revolution to peace only when trust is very high, potentially higher than the cut-off value of war and peace. This is to say,

$$
\begin{aligned}
p^R &> p^W \iff \\
\frac{\pi^P\theta\tau y_O - \left(1-\pi^P\theta\right)\tau y_I + f^R}{1-\pi^P\theta} &> \frac{\left(\pi^W-\pi^P\right)\theta\tau(y_I+y_O) - \pi^W\theta\tau f^W}{1-\tau+2\pi^P\theta\tau} \iff \\
f^R &> \frac{\left(1-\pi^P\theta\right)\left(\left(\pi^W-\pi^P\right)\theta\tau(y_I+y_O) - \pi^W\theta\tau f^W\right)}{1-\tau+2\pi^P\theta\tau} \\
&\quad -\pi^P\theta\tau y_O + \left(1-\pi^P\theta\right)\tau y_I \\
&\doteq \underline{f^R}.
\end{aligned}
$$

If the cost of revolution on the elite is high enough, then the elite doesn't want revolution at all, since it is always dominated by either war or peace. Let us consider the case when revolution is always dominated by war, as the following:

$$\begin{aligned} y_E^R &< y_E^W \iff \\ -f_E^R &< \pi^W(1-\theta)\tau(y_I + y_O - f^W) \iff \\ f_E^R &> -\pi^W(1-\theta)\tau(y_I + y_O - f^W) \\ &\doteq \underline{f_E^R}. \end{aligned}$$

□

Lemma 1. *The value function of the elite's lifetime income $V(p)$ is bounded above and below by some $\bar{V}$ and $\underline{V}$, respectively.*

Proof. To find the solution for the value function, we first characterize important properties of the value function. First, it is bounded. If the expected trade surplus is very close to its lower bound 0, then the elite can always at least start a war and gain from the tax extraction, so we get a lower bound of V:

$$\begin{aligned} V &\geq y_E^W + \beta\pi^W y_E^W + \beta^2\pi^W y_E^W + ... \\ &= \frac{1}{1-\beta\pi^W} y_E^W \\ &\doteq \underline{V}. \end{aligned}$$

Similarly, if in each period the elite expects to get at most $\pi^W(1-\theta)\tau(y_I + y_O + 2) \doteq \bar{y}_E$ when the expected trade surplus is as high as 1 for each group and the probability of the elite staying in power is at most π^W, then we can get an upper bound of V as follows:

$$\begin{aligned} V &\leq \bar{y}_E + \beta\pi^W \bar{y}_E + \beta^2\pi^W \bar{y}_E + ... \\ &= \frac{1}{1-\beta\pi^W} \bar{y}_E \\ &\doteq \bar{V}. \end{aligned}$$

□

With this lemma, we can first prove and discuss proposition 3 which shows that war occurs when trust is low.

Proof. War dominates peace if and only if:

$$\begin{aligned}
V^P(p) &< V^W(p) \iff \\
&\quad \pi^P(1-\theta)\tau(y_I+y_O+2p)+\beta\pi^P E^P[V(p')] \\
&< \pi^W(1-\theta)\tau(y_I+y_O-f^W)+\beta\pi^W E^W[V(p')] \iff \\
p &< \frac{\left(\pi^W-\pi^P\right)(1-\theta)\tau(y_I+y_O)+\beta\pi^W E^W[V(p')]-\beta\pi^P E^P[V(p')]-\pi^W(1-\theta)\tau f^W}{2\pi^P(1-\theta)\tau} \\
&\doteq \underline{p}(p).
\end{aligned}$$

This means that if p is sufficiently small, the gain from trade is smaller than the benefit of war $\underline{p}(p)$, which contains three parts: (1) higher probability of staying in power and getting the current period income: $\left(\pi^W-\pi^P\right)(1-\theta)\tau(y_I+y_O)$; (2) difference in continuation value in the future between war and peace: $\beta\pi^W E^W[V(p')]-\beta\pi^P E^P[V(p')]$; and (3) the cost of war $\pi^W(1-\theta)\tau f^W$. If the cost the war f^W is small, $\underline{p}(p)$ is large, and if meanwhile the trust is low, we have $p<\underline{p}(p)$, implying that the elite chooses war instead of peace. Consider the case that $f^W<\frac{\left(\pi^W-\pi^P\right)}{\pi^W}(y_I+y_O)\doteq \bar{f^W}$. If the trust is at the minimal level, i.e., $p=0$, we have $\underline{p}(0)>p=0$, and the elite prefers war. We can verify this in the following three steps. First, $E^W[V(p')]=E^P[V(p')]=V(\phi)$, as $p=0$ implies $p^+=0$ in both war and peace, and then $p'=\phi$ due to the possibility of type change. Second, $V(\phi)>0$. We know that $\phi\leq\frac{\phi}{\phi+\psi}\leq p^R$, and given $p=\phi$, one possible choice for the elite is to keep having war forever and there will be no threat of revolution, as p will converges to $\frac{\phi}{\phi+\psi}\leq p^R$. In his case, every period, the elite's expected income is $y_E^W=\pi^W(1-\theta)\tau(y_I+y_O-f^W)>0$. The optimal choice for the elite gives higher life-time income than permanent war, so $V(\phi)>0$. This is in fact true for all $p\leq p^R$. Third,

$$\begin{aligned}
p(0) &= \frac{\left(\pi^W-\pi^P\right)(1-\theta)\tau(y_I+y_O)-\pi^W(1-\theta)\tau f^W}{2\pi^P(1-\theta)\tau}+\frac{\beta\pi^W[V(\phi)]-\beta\pi^P[V(\phi)]}{2\pi^P(1-\theta)\tau} \\
&> 0+0 \\
&= 0.
\end{aligned}$$

This shows that when the trust is as low as 0, the elite prefers war. Moreover, if $V(p)$ is continuous at $p=\phi$, $\underline{p}(p)$ is continuos at $p=0$. Then given $0<\underline{p}(0)$, there exists a neighborhood of 0, denoted as $[0,p_E^W)$, for any $p\in[0,p_E^W)$, we have $p<\underline{p}(p)$. In other words, in this low trust region, war is started because there is little to gain from trade. □

Proposition 4 shows that "surprisingly", war also occurs when trust is too high, because the elite is afraid of even higher trust leading to revolution. We provide the proof and the discussion below.

Proof. Consider the situation $p = p^R$. If peace is chosen, with probability $q^R = p^R q_H + \left(1 - p^R\right)(1 - q_L)$, the trade outcome is good and $p' > p^R$, which triggers a revolution in the next period. Then

$$V^P\left(p^R\right) \leq \pi^P(1-\theta)\tau(y_I + y_O + 2p^R) + \beta\pi^P\left(-q^R f_E^R + \left(1 - q^R\right)\bar{V}\right).$$

A sufficient condition for $V^P\left(p^R\right) < V^W\left(p^R\right)$ is:

$$\begin{aligned} & \pi^P(1-\theta)\tau(y_I + y_O + 2p^R) + \beta\pi^P\left(-q^R f_E^R + \left(1 - q^R\right)\bar{V}\right) \\ < \;& \pi^W(1-\theta)\tau(y_I + y_O - f^W) + \beta\pi^W \underline{V} \iff \\ f_E^R \; > \;& \frac{\pi^P(1-\theta)\tau(y_I + y_O + 2p^R) - \pi^W(1-\theta)\tau(y_I + y_O - f^W) + \beta\pi^P\left(1 - q^R\right)\bar{V} - \beta\pi^W\underline{V}}{\beta\pi^P q^R} \\ \doteq \;& \underline{f_E^R}. \end{aligned}$$

We can see that given f_E^R is sufficiently large, the elite chooses to go to war when the trust is as high as p^R. In fact, we can see that if p increases from below, before it reaches p^R, war is already preferred by the elite to peace. This is because if trust is slightly smaller than p^R, the threat of revolution during peace – the probability of having a high enough trust that leads to revolution – is only slightly smaller and the cost of peace for the elite is still large. In other words, there exists a neighborhood of p^R, denoted as $(p_E^R, p^R]$, for all p in this neighborhood, we have

$$\begin{aligned} f_E^R \quad > \quad & \frac{\pi^P(1-\theta)\tau(y_I + y_O + 2p) - \pi^W(1-\theta)\tau(y_I + y_O - f^W) + \beta\pi^P\left(1 - q^R\right)\bar{V} - \beta\pi^W\underline{V}}{\beta\pi^P q^R} \\ \implies \quad & V^P\left(p^R\right) < V^W\left(p^R\right). \end{aligned}$$

War is preferred by the elite when $p > p_E^R$. □

Part IV

Curriculum Vitae

Curriculum Vitae

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2007	Intern, United Nations Conference on Trade and Development, Geneva
2005 - 2007	Research Assistant, responsAbility Investments AG, Zurich
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